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ABSTRACT

Providing an Indian Studies field course in natural science, this dissertation includes: a sourcebook of pertinent reference materials; reservation specific sample lesson plans; natural science roadlogs; a syllabus designed to stress natural science processes and to serve as a unifying factor for field work, lecture, and course discussions. Emphasis is on geographical and ecological concepts, climatic and geological processes, and the natural habitats of North Dakota including discussion of North Dakota vertebrates and early man and his environment, geologic features and history, vegetation and animal life of each of the four North Dakota American Indian reservations. The following processes are identified as being used in the development of the syllabus and sourcebook: research and experimentation in teaching methods; design and implementation of a natural science field course based upon the syllabus; field observations of North Dakota geology and biology; interviews with resource persons on the various syllabus topics; and a study of pertinent literature. Maintaining that American Indians identify strongly with natural science concepts because their cultures have traditionally reflected the inter-relationship between man and nature and man's dependency upon nature, this thesis presents extensive information relative to the Turtle Mountain, Fort Berthold, Devils Lake Sioux, and Standing Rock Sioux Indian reservations. (Author/JC)

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NATURAL SCIENCE OF THE GREAT PLAINS AS IT RELATES TO THE AMERICAN INDIAN: A SYLLABUS AND SOURCEBOOK

by

Mary E. Bluemle

Bachelor of Arts, Marycrest College, 1958
Master of Science Teaching, University of North Dakota, 1967

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Submitted to the Graduate Faculty
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in partial fulfillment of the requirements
for the degree of
Doctor of Education

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Through scholarships, grants, and part-time employment as an instructor, the Center for Teaching and Learning and the State Board of Higher Education have made my doctoral studies financially possible.

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ABSTRACT

This dissertation, which includes a sourcebook of pertinent reference materials, sample lesson plans, and natural science roadlogs, is an initial attempt at providing an Indian Studies field course in natural science. It also includes a syllabus which stresses natural science processes and serves as a unifying factor for field work, lecture, and course discussions. The dissertation stresses geographical and ecological concepts, climatic and geological processes, and the natural habitats of North Dakota. It includes discussions of North Dakota vertebrates and early man and his relation to his environment; discussions of the geologic features, geologic history, vegetation and animal life of each reservation; and sample lesson plans and roadlogs for each reservation.

The need for natural science field courses is especially acute for American Indian college students. Despite average or above-average intelligence, Indian students often find the social environment and value orientation of colleges and universities alien and they either fail or have difficulty in adjusting to college life. The need for Indian Studies courses in the humanities, social sciences, and education is being met at the University of North Dakota and elsewhere, but Indian Studies courses in natural science have not been developed. This dissertation is an attempt to meet such a need.

In preparation for the actual compilation of this dissertation, I made extensive field observations during the summers of 1968 through

1972 throughout North Dakota. Since then, I have conducted research and read extensively on the geology and biology of North Dakota's four Indian reservations. In the years since 1972 I have taught various courses in natural science, biology, and geology to Future Indian Teachers enrolled at the University of North Dakota, on the university campus, in the field, and on the reservations. During the summer of 1975, I taught a course which closely paralleled the content of this dissertation (Arts and Sciences 250, four semester hours) to Future Indian Teachers on the Standing Rock Sioux and Fort Berthold Indian Reservations in North Dakota. The students were able to relate the course content to their home environments.

Natural science deals with the activities and interrelationships of all living and non-living things and it includes such topics as field geology, climatology and meteorology, soils, astronomy and field biology. A well-integrated natural science course should deal with several of these topics. It should enable students not majoring in science to gain a balanced perspective of the essence of natural science and its importance to them. American Indians identify strongly with natural science concepts because their cultures have traditionally reflected the interrelationship between man and nature and man's dependency on nature.

CHAPTER I

INTRODUCTION

Natural science is the study of nature. It includes all living and non-living things, their activities, and interrelationships (Pimentel, 1963). For what are often considered practical reasons, the study of natural science is usually subdivided into field geology, climatology and meteorology, soils, astronomy, and field biology. Such a separation, however, often fails to provide the student with an overall natural science perspective of an integrated field-oriented course (Pimentel, 1963). An overall natural science perspective is particularly important, especially for students who are not pursuing a major in one or more of the natural science fields. The organization of the basic subject matter for courses with such potential is the topic of this dissertation.

Objectives, Scope and General Background

The purpose of this dissertation is to provide a syllabus and sourcebook for a field study of the natural science of the Great Plains and especially the four Indian Reservations of North Dakota. The field study is intended for the non-scientist: teachers and students and anyone who is interested in the natural science of North Dakota and the northern plains, but especially for American Indian college students and their teachers.

The dissertation includes a syllabus (Chapter II) and a sourcebook (Chapters III and IV). Chapter V is a summary which also provides some suggestions for extending the work described in the previous chapter. The syllabus, or course plan, delineates one of many ways in which a teacher might organize a field course, using as a base the sourcebook and the supplementary materials listed in Appendices A and B. The sourcebook as well as Appendices C and D, the sample lessons and roadlogs, provide an introductory background for a variety of field courses in natural science. Because I am a geologist I have stressed geology. Included as an integral, but more limited, part of the sourcebook, are discussions of the climate and soils of North Dakota, and of the common plants and vertebrates, including man. The discussion of the latter areas, even though it incorporates much of my own field experience, is referenced to secondary sources.

My basic interest in the development of the natural science course goes back about four years to when I was tutoring American Indian students. I became concerned at the high drop-out rate among American Indian college freshmen at the University of North Dakota and, from what I came to understand, at other colleges and universities in the United States as well. For a variety of reasons, despite intelligence and scholastic preparation for college work, Indian students have often found the social environment and value orientation of colleges and universities alien and have had serious problems adjusting to collegiate life. I believed that a field course, evolving out of the natural science of North Dakota and its Indian Reservations, would be a relevant way for North Dakota Indian students to learn science. Such an approach would assure that Indian students would not be fully removed from aspects of their own culture and physical environment. It seemed, from my perspective, that such a course would also be a recognition of the importance of Indian culture.

A variety of courses in the humanities, social sciences and education have been developed within the area of Indian studies at the University of North Dakota and elsewhere, but the need for Indian studies courses in the sciences exists as well. The study of the natural science of the northern plains and traditional plains Indian cultures are complementary and it seemed to me that a university field course in natural science of the plains would provide a logical transition between traditional Indian cultures and value systems and the sciences commonly taught at the university. I entered graduate school to design a course that would fill this need.

Development of the Syllabus and Sourcebook

My interest in developing a natural science course was facilitated by several opportunities to teach related courses in science to Indian students enrolled in the University of North Dakota's Future Indian Teacher Program. It was facilitated also by the opportunities I had during the five summers of 1968-1972 to make extensive field observations. During these years I visited and familiarized myself with the glaciated terrain of North Dakota as well as with some sections of unglaciated terrain along the Missouri and Little Missouri Rivers. In addition, I studied the geology and biology of the four North Dakota Indian Reservations, Standing Rock, Fort Berthold, Devils Lake Sioux, and Turtle Mountain, during the summer of 1972.

In the summers of 1972 and 1973, I taught Biology 101 and 102 to the Future Indian Teachers (FIT) at each of the four reservations.

In the fall semester, 1973, I team taught an FIT course which integrated science and math (CTL 440) at the University of North Dakota. In the spring semester, 1975, I taught physical geology 101 to freshmen FIT students and during the following summer session I used the sourcebook presented here, (Chapters III and IV), as a guide in developing course outlines for the FIT students at the Standing Rock and Fort Berthold Reservations. The latter course was listed as Arts and Science 250, the Natural Science of the Great Plains (4 credits). Each student taking the Natural Science of the Great Plains had the option of having the course listed on his transcript as credit toward a minor in Indian Studies (Art Raymond, Department of Indian Studies, personal communication, May 14, 1975). Each group of students who participated in the natural science course evaluated my methods of approach, expressed what they believed they understood and had achieved, and suggested needed changes. These changes are incorporated in the syllabus and course outline.

The experience I gained from the courses I taught, most especially the Natural Science course, provided insight into those aspects of science that should be stressed, those which seemed to have the greatest application to the more traditional understanding of nature among Indian students, and ultimately the topics with the most intrinsic interest. They included those topics with field application that could be observed close to the Indian communities in which they were being studied.

As I was interested in a field course, I attempted to seek out as many different kinds of resources as possible. Persons who provided assistance were members of the geology faculty at the University of

North Dakota, personnel of the North Dakota Geological Survey, biologists at the Northern Prairie Wildlife Research Center as well as historians, biologists, anthropologists, archaeologists, and specialists in curriculum, testing, and evaluation at the University of North Dakota. These people helped me to draw guidelines for writing this dissertation.

I reviewed a variety of literature including the subject areas discussed in this paper, curriculum development, and methods of testing and evaluation. What was significant was the limited amount of literature which attempts to relate science to the Indian community. Elementary school curricula that recognize the diversified cultural wealth of the American Indian peoples in the Dakotas and Manitoba are now being developed (Sealey et al., 1975; United Tribes of North Dakota Development Corp., 1974), but little is currently in use in schools. A number of books dealing with sub-topics of this dissertation topic that are especially valuable for any students of the northern Great Plains are listed in Appendix A or cited among my references to this dissertation. However, there has been no previous work dealing with the natural science of the northern plains designed especially for American Indians.

In summary, I have used the following processes of developing the syllabus and sourcebook: (1) research and experimentation in teaching methods; (2) designing and teaching a natural science field course based on this syllabus; (3) field observations of the geology and the biology; (4) interviews with resource persons on the various topics treated in this syllabus; and (5) a study of pertinent literature.

CHAPTER II

SYLLABUS

Introduction

This chapter is an outline of a natural science course that I developed for use principally with Future Indian Teachers (FIT). It arises from several years teaching field-involved courses to Future Indian Teachers and it represents a synthesis of what I consider to be some of my most successful efforts. Successful, in this case, implies that the students were able to relate the content of the courses to the environments in which they live. In addition, my approaches to the content and the course material itself created a high level of interest among the students. My intention in presenting a course outline is not to suggest a model but to share my experiences with others in the hope that they can reflect upon my basic organization, use what I have learned, and expand upon my field activities.

The northern Great Plains, as a geographic region, is so vast and so varied in its natural history that no one course can do it justice. Each person who teaches a course in the natural science of the northern plains will do so in a different manner, because each instructor must be true to his own personality, and should consider the needs of individual students. A field course when planned with care, allows for many successful approaches provided each lesson is thoughtfully outlined, whether it involves field work, field trips, or classroom activities.

Organization of a Sample Course

I. Objectives

   A. Insight into the natural science of North Dakota.

   B. Insight into the relationship between the various environments of the northern plains and the Indian cultures which developed within, and were dependent upon, these environments.

II. Student requirements

   A. Keep records of daily observations in natural science.

   B. Participate in class field trips which include pertinent dialogue during trips and personal observations recorded in journals.

   C. Read materials directly relevant to the field work.

   D. Complete a topic of special interest to the student to be chosen during the first days of the course and discussed periodically with the teacher.

   Examples of some projects:

   1. Study of vertebrate tracks along stream or slough: description of habitat; photos and drawings of tracks; identification (Murie, 1954) and a brief summary of probable animals that made the tracks (Burt & Grossenheider, 1964; Collins, 1959).

   2. Study of common grasses of windbreaks, pastures, or native prairies: pressing, mounting, and identification of grasses (Allen, 1967; Stevens, 1963; Johnson & Nichols, 1970); description of habitat where each species of grass was found.

   3. Observations of a golden eagle aerie in the Killdeer Mountains: telephotos of eagles in flight; photos of actual nest, pellets and other sign; daily log of eagles' actions observed through binoculars; description of habitat.

4. Comparison of catfish feeding on domesticated grain (such as wheat and barley) submerged during the summer, 1975, flooding of Lake Sakakawea with channel catfish caught in the Missouri River channel south of Garrison Dam.

5. Location, description of habitat, and stage of growth best-suited for edibility and preservation of prairie turnip found in native grassland. Turnip patches were located and several turnips were gathered every two days from each turnip patch. Each time some turnips were pressed for identification purposes. Some were tasted by the students and older women in the community who commonly use the turnip as a summer vegetable and dry it for winter use in stew. These cooks helped the students judge the time the samples were still tender, but sufficiently developed to preserve well, and the pressed specimens from that collection date were so identified.

E. Summarize and evaluate the course by means of a brief abstract and several one-hour tests.

III. Course Plan

I included the following topics in the course Natural Science of the Great Plains, and I designed them into a lecture/discussion format. I am convinced that field work is the best process by which natural science can be learned and remembered, but unless there is a unifying factor to the field work, the students will not gain an overall perspective of natural science. The outline below, and the lecture/discussions which developed from this outline, are the skeleton supporting the course. Field work and the student's individual learning experiences gave flesh and life to this skeleton.

- A. Geography
  - 1. Location
  - 2. Population
  - 3. Climate, ancient and modern
  - 4. Soils
- B. Landscape of North Dakota
  - 1. Geological processes
    - a. Weathering
    - b. Fluvial
    - c. Mass wasting

        - d. Glacial
        - e. Eolian
    - 2. Unglaciated region
    - 3. Glaciated region
        - a. Areas of glacial deposits
        - b. Areas of melt water deposits
    - 4. Drainage pattern effects on North Dakota landscape
- C. Biology
    - 1. Ecological concepts
        - a. Biosphere
        - b. Ecosystem
        - c. Niche
        - d. Population
        - e. Community
        - f. Ecological succession and species diversity
    - 2. Biology of North Dakota
        - a. Introduction
        - b. Natural habitats
            - 1) Tall grass prairie
            - 2) Modified tall grass prairie
            - 3) Medium to tall transition grassland
            - 4) Mixed prairie
            - 5) Broadleaf deciduous woodland
            - 6) Evergreen woodland
            - 7) Sparse grassland in badlands
            - 8) Hardwood draws
            - 9) Prairie potholes
    - 3. General discussion of North Dakota vertebrates
        - a. Fishes
        - b. Amphibians and reptiles
        - c. Birds
        - d. Mammals
    - 4. Man's influence on North Dakota biology
- D. Man in North Dakota
    - 1. Paleo-Indian stage
    - 2. Archaic stage
    - 3. Sedentary stage
    - 4. Historic stage
- E. Natural science of selected Indian Reservations
    - 1. Geologic features
    - 2. Geologic history
    - 3. Vegetation
    - 4. Animal life
    - 5. Field studies
        - a. Lessons
        - b. Roadlogs
- F. Astronomy[1]
- G. Meteorology[1]

---

[1] Subdivisions of natural science, which the individual teacher may wish to use in designing a syllabus, but which I have not included in the sourcebook part of the dissertation, Chapter III and IV. Some references to these topics are listed in Appendix A.

IV. Sample course credit and time allotment: Natural Science of the Great Plains

- A. Credit: 4 semester hours
- B. 60 contact hours approximates 4 semester hours
  - a. 1 lecture hour = 1 contact hour
  - b. 3 laboratory (field) hours = 1 contact hour
- C. Time allotted course: 5 hours/day; 5 days/week for 4 weeks

Organization of the Study

In this chapter I have given a sample course outline, or syllabus. Chapter III is a general discussion of the natural science of North Dakota. Chapter IV includes discussions of the geology and biology pertinent to each reservation. Chapter V includes a summary of my study and my recommendations for further development of field courses related to science. References and resource materials which deal with topics in the syllabus are listed in Appendices A and B. Sample field lessons and sample roadlogs for each reservation are found in Appendices C and D. A history of the establishment of the North Dakota Indian Reservations is given in Appendix E.

CHAPTER III

OVERVIEW OF NATURAL SCIENCE IN NORTH DAKOTA

Geography

Location and Size

North Dakota lies at the center of the North American continent. To the north are the Canadian provinces of Saskatchewan and Manitoba; to the east is Minnesota. South Dakota and Montana are to the south and west. Except for the North Dakota-Minnesota boundary (the Red River of the North and the Bois de Sioux River), all North Dakota boundary lines are straight, politically devised, without regard to physical features. Thus the 49th parallel describes the northern boundary; 45°55' marks the south boundary; and 104°02' west marks the western boundary of the state. The total land area of the state is 60,457 square miles. Water covers 1,208 square miles (U.S. Dept. of Commerce, 1967).

The U.S. Bureau of Indian Affairs administers 841,575 acres of land (as of 1970) in North Dakota (U.S. Dept. of Commerce, 1974). Of this land, 151,608 acres were assigned to the Indian tribes. All or parts of five Indian reservations occur in North Dakota: Fort Berthold, Fort Totten, Sisseton-Wahpeton, Standing Rock, and Turtle Mountain (Figure 1).

Population

As of April 1, 1970, there were 617,761 people in North Dakota. The state ranks 17th in size and 45th in population. American Indians

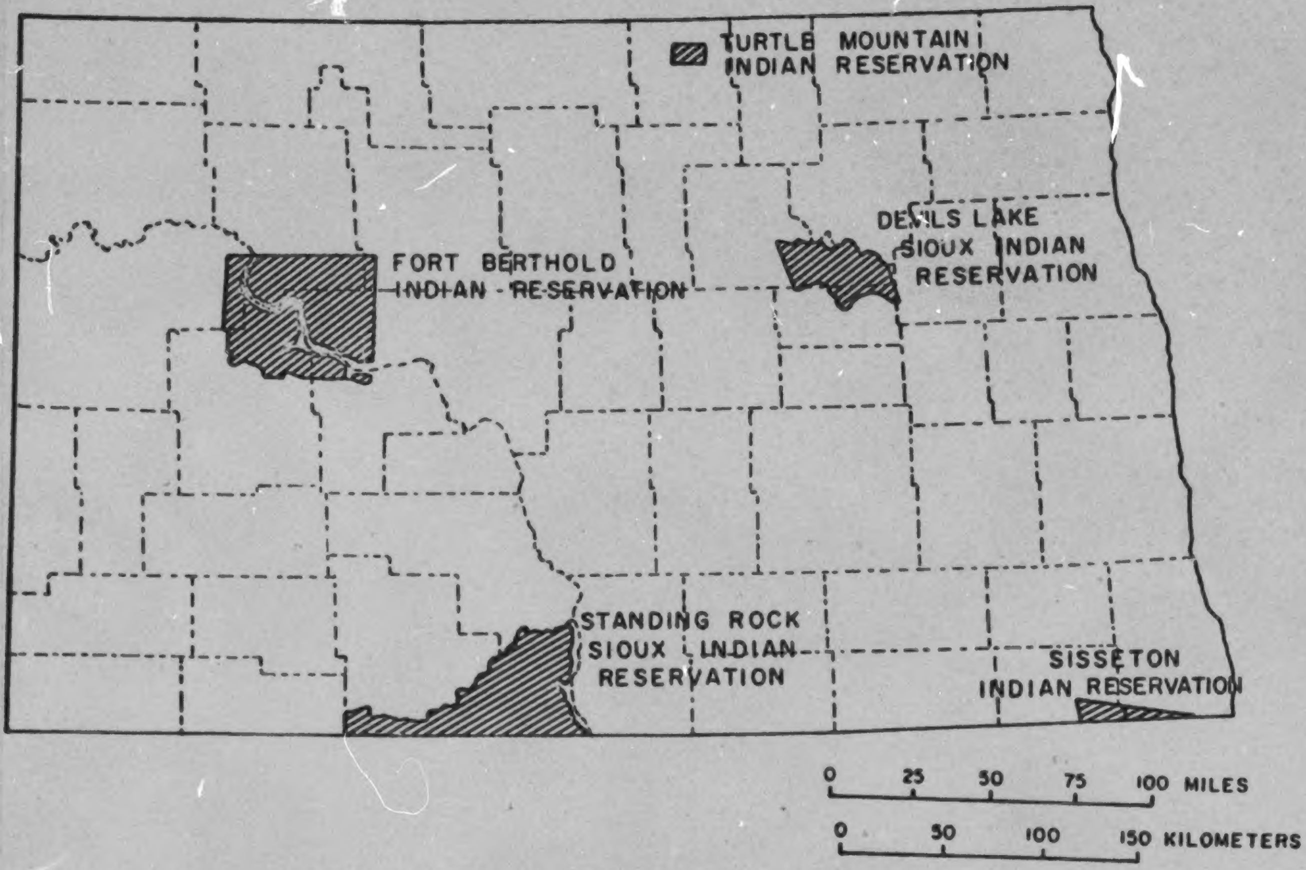

▨ TURTLE MOUNTAIN INDIAN RESERVATION
FORT BERTHOLD INDIAN RESERVATION
DEVILS LAKE SIOUX INDIAN RESERVATION
STANDING ROCK SIOUX INDIAN RESERVATION
SISSETON INDIAN RESERVATION
0 25 50 75 100 MILES
0 50 100 150 KILOMETERS

Figure 1. Map of North Dakota showing the locations of the Indian Reservations. Adapted from U. S. Dept. of Commerce, 1974.

living on reservations comprise 2.4% of the population or about 15,000 people (Torkelson, 1973).

Climate

Ancient Climate

North Dakota's climate has changed often throughout geologic time (Figure 2), but it has generally been warmer than it is now. Fossil records show that, during Cretaceous and early Tertiary time (135 million years ago until 50 million years ago), palms, *Metasequoia*, *Sassafras*, *Ginkgo*, *Fagus*, and other typical temperate and subtropical plants ranged throughout North Dakota (Rudd, 1951).

The western United States mountains, the Rocky Mountains, began to rise 70 to 80 million years ago at the close of Cretaceous time and have continued to do so to the present day. As they rose, they formed a barrier to the movement of air masses and cut off the inflow of humid air and precipitation from the Pacific Ocean (Sears, 1935). As a result, the Great Plains gradually became semiarid as they are today.

The past three million years, the Pleistocene Epoch, has been a time of cooler, more humid climate marked by several periods of glaciation (Bryson, Baerreis, and Wendland, 1970). It generally has been theorized that, as the glacial climate intensifies, tundra, scrub, conifer, and deciduous forests tend to shift as belts before the advancing ice and then follow it back as it melts (Sears, 1935), but no such succession can be shown to have occurred in North Dakota. The ice that advanced into North Dakota moved into a semiarid grassland area for the North Dakota plains have been in the "rain shadow" of the western mountains since early Tertiary time, 65 million years

SYSTEM	GROUP OR FORMATION		DOMINANT LITHOLOGY	MILLIONS OF YEARS AGO
QUATERNARY	Coleharbor		Glacial Drift	3
TERTIARY	White River		Clay, Sand, Limestone	
	Golden Valley		Clay, Sand, Silt	
	Fort Union Group	Sentinel Butte	Sandstone, Shale, Lignite	
		Tongue River	Sandstone, Shale, Lignite	
		Cannonball, Tullock, Ludlow	Marine Sandstone, Shale	70
CRETACEOUS	Hell Creek		Sandstone, Shale and Lignite	
	Montana Group	Fox Hills	Marine Sandstone	
		Pierre	Shale	
		Niobrara	Shale, calcareous	
	Colorado Group	Carlile	Shale	
		Greenhorn	Shale, calcareous	
		Belle Fourche	Shale	
	Dakota Group	Mowry	Shale	
		Newcastle	Sandstone	
		Skull Creek	Shale	
		Fall River	Sandstone and Shale	
		Lakota	Sandstone and Shale	135
JURASSIC	Morrison		Shale and Clay	
	Sundance		Shale, green & brown, Sandstone	
	Piper		Limestone, Anhydrite, Salt and red shale	180
TRIASSIC	Spearfish		Siltstone, Salt and Sandstone	225
PERMIAN	Minnekahta		Limestone	
	Opeche		Shale, Siltstone and Salt	270
PENNSYLVANIAN	Minnelusa		Sandstone and Dolomite	
	Amsden		Limestone, dolomitic, Shale and Sandstone	325
MISSISSIPPIAN	Big Snowy Group	Heath	Shale	
		Otter	Sandstone	
		Kibbey	Limestone	
	Madison		Limestones and Evaporites	
	Bakken		Siltstone and Shale	350
DEVONIAN	Three Forks		Shale, Siltstone and Dolomite	
	Birdbear		Limestone	
	Duperow		Dolomite and Limestone	
	Souris River		Dolomite and Limestone	
	Dawson Bay		Dolomite and Limestone	
	Prairie		Halite	
	Winnipegosis		Limestone and Dolomite	400
SILURIAN	Interlake		Dolomite	440
ORDOVICIAN	Stonewall		Dolomite and Limestone	
	Stony Mountain Fm.	Gunton Mbr.	Dolomite and Limestone	
		Stoughton Mbr.	Argillaceous Limestone	
	Red River		Limestone and Dolomite	
	Winnipeg Group	Roughlock	Calcareous Shale & Siltstone	
		Icebox	Shale	
		Black Island	Sandstone	500
CAMBRIAN	Deadwood		Limestone, Shale and Sandstone	620
Precambrian Rocks				

Figure 2. Stratigraphic column of North Dakota. Dashed lines represent major regional unconformities.

ago. It is likely that the ice age was preceded by cold, relatively dry conditions (Sears, 1935).

The cool, humid periods of glacial advance, alternating with the warmer, drier interglacial periods, resulted in successive destruction and reestablishment of all vegetation (Sears, 1935). Presumably, the glaciers moved southward from a region of tundra and boreal, coniferous forest. Along their western flank, the glaciers advanced over transition aspen woodland into the prairie of Canada and North Dakota. The advancing ice obstructed the north-flowing drainage systems, and increased the moisture that resulted from ponding of streams and decreased evaporation permitted the invasion of a few pioneer forest species (Rudd, 1951). Aspen woods probably developed in places ahead of the advancing glaciers whereas willow thickets and wet meadows developed in low areas and prairie remained on the drier hilltops. Similar conditions probably existed as the glaciers receded. Beds of spruce and tamarack have been found buried beneath the surface within Lake Agassiz sediments in the Red River Valley near Grand Forks (Hansen and Kume, 1970).

After the glaciers receded from North Dakota about 10,000 years ago, the area had short summers, warm enough however to allow abundant plant growth for grazing animals. Klein (1974) has shown that, in the Ukraine, winters were both long and cold south of the retreating glaciers, but they also were rather dry, so the summer growth was not buried beneath deep snow and animals were able to find feed the year around. It seems likely conditions were similar in North Dakota.

Since the last glaciers melted from North Dakota, the climate has changed several times. Glacial ice was still present on the

Turtle Mountains and the Missouri Coteau between about 12,000 and 9,000 years ago, but it was so well insulated by a cover of thick glacial sediment it probably had little effect on the climate (Clayton, 1967).

During the 3,500-year interval between 12,000 and 8,500 years ago, eastern North Dakota had a cool, moist climate which may have allowed the growth of hardwood forests. As the climate became drier and warmer between about 8,500 and 4,500 years ago during what is known as the Altithermal (maximum temperature) period (Bryson and Wendland, 1967), prairie grasses replaced the woodlands. The southwestern part of the state was probably covered by sage and short grasses, very much like much of Wyoming and eastern Montana today (Dort and Jones, 1970). According to McAndrews, Stewart, and Bright (1967), who studied pollen samples from sediments collected from potholes in the northern plains, the composition and position of the major vegetation units has changed drastically since the end of the glaciation. Areas that are now prairie were covered by spruce until about 10,000 years ago. McAndrews (1966) showed that areas of northwestern Minnesota that are now covered by deciduous forest were prairie about 4,000 years ago. Thus, during the period from 10,000 until 4,000 years ago, the prairie vegetation extended into parts of Minnesota that are today wooded. The drier climate was also reflected in lowered lake levels during this time interval.

The climate became considerably wetter beginning about 3,000 to 4,000 years ago, allowing woodlands to spread over much of North Dakota. Between 2,500 and 1,500 years ago, generally cool, wet conditions prevailed with heavy winter snowfall (Dort and Jones, 1970). This represented a partial return to conditions similar to those at the end of the ice age although glaciers did not form in North Dakota. A return to warmer conditions which began about 1,500 years ago, lasted until about 100 years ago. During much of that 1,400-year period, North Dakota probably had somewhat more rainfall than it does today. The relatively dry climate of the past 100 years has seen an expansion of short-grass prairie eastward across the state (Dort and Jones, 1970). The decreased precipitation is reflected in the considerable shrinking of lakes such as Devils Lake and Stump Lake. To some extent, however, the past ten years has seen a partial reversal of this trend, with lake levels returning to those of 70 and 80 years ago in response to increased precipitation (Callender, 1968).

Modern Climate

North Dakota's mid-continent location results in a modern climate which is continental, characterized by large variations in the seasonal and daily temperatures, moderate to light precipitation, which is irregular in coverage, low relative humidity, much sunshine, and almost continual winds (Jensen, 1974).

From 2,600 to 2,800 hours of sunshine occur annually with 25% of it during July and August. Along with eastern Montana this is more sunshine than any other area along the Canadian border. The contrast in high radiational energy at the surface in June is due to high sun angle, and 16 hours of daylight, whereas comparatively low radiational energy at the winter solstice, because of the low angle of the sun and only nine daylight hours, contributes to large seasonal temperature changes and a general north-south temperature gradient across North Dakota (Borchert, 1950).

North Dakota's plains topography allows weather systems to travel swiftly over the state resulting in frequent changes. Warm, moist air masses and cold, dry polar air masses are both unimpeded by mountain chains so that they overflow the state with only minor changes in their original characteristics. Air masses originating in the Pacific Ocean lose moisture as they rise to pass over the Rocky Mountains and are warmed as they descend the mountains before progressing over North Dakota.

Topography does contribute somewhat to state-wide temperature and precipitation patterns. Surface elevations are highest in the southwest and lowest in the northeast. The Missouri Coteau, Turtle Mountains, and Killdeer Mountains affect precipitation locally. Though the Turtle Mountains of Bottineau and Rolette Counties average only 400 to 800 feet above the surrounding area, their abrupt rise produces significant irregularities in temperature patterns. A cold pocket is found southwest of the mountains due to cold air draining into the lower reaches of the Souris River basin; on the other hand the prevailing northwesterly winds are compressed and warmed as they descend the southeasterly slopes (Jensen, 1974).

North Dakota's mean yearly temperature averages vary from 3°C (37°F) in northern Cavalier and Towner Counties in the northeast to 6°C (43°F) in the extreme southeast and southwest corners of the state (Bavendick, 1952). In January the average temperature ranges from -17°C (2°F) in the northern Red River Valley to -8°C (17°F) in southwest North Dakota where chinook winds occasionally overspread the area from the lee slopes of the Rocky Mountains. Centers of high pressure systems tend to move through the eastern portion of the state more often than the western portion resulting in lower average temperatures in the east. High and low temperatures reflect the continental climate with a record low temperature of -51°C (-60°F) recorded at Parshall, Mountrail County, in the winter of 1936, and a record high of 49°C (121°F) recorded in Steele, Kidder County, the following summer (Bavendick, 1952).

Warming occurs most rapidly in April and the characteristic winter gradient is gone by May. (This winter gradient is characterized by the coldest average temperatures in the contiguous United States in northeast North Dakota as opposed to the moderately cold southwestern counties.)

North Dakota's monthly transition from summer-to-fall-to-winter is in sharp contrast to the abrupt winter-summer transition which results in almost no springtime. July temperatures average from 19°C (67°F) east of the Turtle Mountains to 23°C (73°F) in extreme southeast North Dakota. During September and October, a continued intensification of a warm temperature ridge, and its associated warm weather and greater rainfall, occurs in the Red River Valley. Not until mid-November has the state regained the typical wintertime temperature gradation with lower temperatures in the northeast and relatively higher ones in the southwest. By November, average state temperatures are below freezing, and toward the end of the month, the first subzero winter temperatures usually occur.

The frost-free season usually extends from mid-May to early September. June, July and August temperature patterns feature north-south warm temperature ridges with cooler north-south troughs between these. The coolest areas in the summer months are along the Canadian border in Towner, Cavalier, Renville and Burke Counties. The extreme southeast and south-central areas are the warmest with temperatures averaging in the low 70s in July and August (Jensen, 1974).

North Dakota's annual precipitation ranges from 13 inches in the northwest to greater than 20 inches in parts of the Red River Valley and the southeast. Lines of equal precipitation show a general north-south orientation with an increase of one inch of precipitation for every 50 miles shift eastward.

Winter precipitation is light because moisture-laden low pressure systems usually follow paths to the south of the state. North Dakota receives less snow than any other state on the Canadian border. In fact, deep snow is rarely found, with maximum snow depth ranging from nine inches in the warmer southwest, to 15 inches in the northeast. The deepest snow pack since 1897 was 40 inches in the southeast in March, 1969. Low pressure systems originating on the eastern slopes of the Canadian Rocky Mountains have already lost their moisture on the seaward slopes of the mountains and in winter, as the weather systems move southeastward across North Dakota, they are characterized more by the cold air masses that follow them than associated snowfalls (Jensen, 1974).

A marked decrease in rainfall in the autumn months usually combines with mild weather to give North Dakota several weeks of Indian Summer. Chances of measurable precipitation in late October and early November are lower than during any other season. Average November precipitation ranges from one half inch in the west to one inch in the eastern part of the state, and the first measurable (0.1 inch or more) snowfall most years is also in November, though measurable amounts can be recorded as early as September about one year out of ten in the western or northern parts of the state (Jensen, 1974).

In three parts of the state, the general increase of precipitation in an easterly direction does not apply. One such area is in the southwest where the annual precipitation of more than 16 inches is higher than in surrounding areas. Higher precipitation here is largely a result of higher elevations (Bavendick, 1952). The second area is in the north-central part of the state where the annual precipitation of less than 16 inches is somewhat lower than in surrounding areas. Relatively lignt precipitation here is caused primarily by air moving downhill from all but a southerly direction which works against precipitation. The third area where precipitation is significantly different than in surrounding areas is the Turtle Mountains. Generally, the difference between the Turtle Mountains and the surrounding prairie is about 10 to 11 inches of precipitation per year. Though this is based on weather records kept only since 1968 at the International Peace Garden by the Canadian Meteorological Service, the long-term moisture variation between the prairie and the Turtle Mountains must be biologically significant, for the upland area supports an aspen forest. Wier (1960) reported an average precipitation of approximately 19 inches for the Canadian side of the Turtle Mountains although he did not say where the records come from. He stated that this includes about 45 inches of snow annually.

North Dakota blizzards are caused by deepening low pressure systems migrating eastward from their origins on the lee side of the Rocky Mountains. Blizzards in North Dakota are generally caused by low pressure systems originating in southern Alberta or southern Colorado

(Jensen, 1974). About 40 lows originate in each of these regions each season and in an average year only two or three blizzards will develop from each region.

Alberta lows move rapidly and they are accompanied by subzero temperatures. Consequently they are a greater threat to loss of human life and livestock than are the slower moving, warmer blizzards that originate in Colorado. These last longer, but they are less hazardous because their tendency to stagnate and meander gives time for blizzard warnings to be widespread.

Average wind speeds are greatest in late winter and early spring, lowest in summer and 10 to 20 percent higher in the Red River Valley than the rest of the state. The valley seems to channel a strong north and north-northwest flow and also a strong south and south-southeast flow. The average surface wind speed in North Dakota, according to Visher (1966), is 12 mph.

Soils

Climate has probably had the most direct influence on soil development, even though parent rock and plants also contribute to soil development. Glaciated areas of North Dakota are covered by sediments deposited by glaciers and glacial melt waters. These sediments are a mixture of materials derived by glaciers that moved out of northwestern Ontario and central Manitoba into North Dakota. As they advanced, the glaciers engulfed and ground up granitic gneiss, greenstone, dolomite, shale, and other common crustal rocks. The resulting glacial sediment is a mixture rich in the mineral nutrients on which plants thrive. Unglaciated areas of North Dakota, usually covered by a single parent rock such as shale, do not have such a diversity of mineral nutrients (U.S. Dept. of Agriculture, 1964).

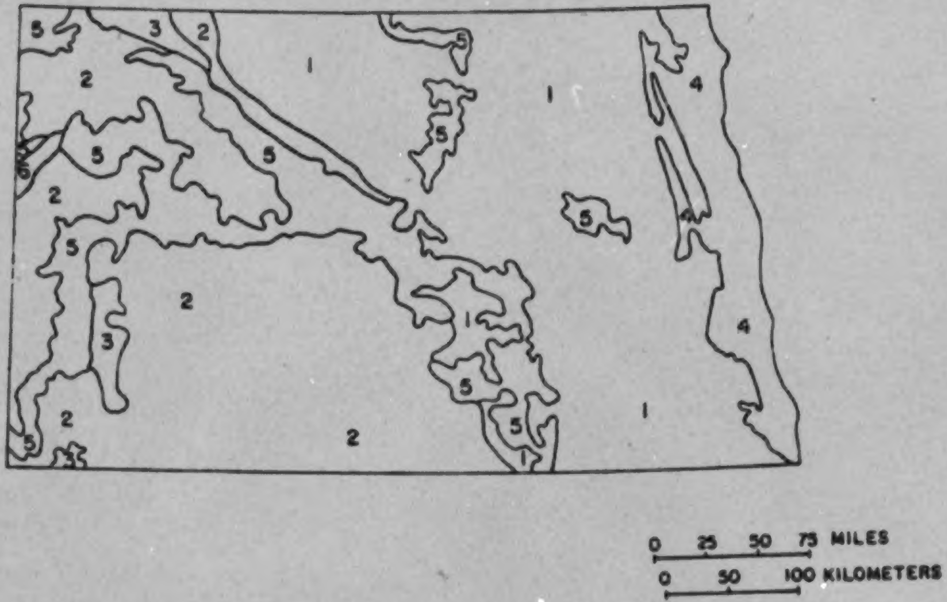
Most of North Dakota's soils developed in grassland areas and soils which develop beneath grasslands are much different than those formed under forest vegetation (Eyre, 1968). Forest soils derive their organic materials from a combination of leaf-fall and a discontinuous cover of herbaceous plants. The result is a loose, crumbly, well-aerated layer of material, which is incorporated into the mineral horizons by the mechanical action of rodents and insects. In grasslands, the dense organic "sod" or "turf" accumulates as it dies. The living grass forms a dense, matted root network. The humus that results from the combination of decaying grass and the root network is implanted in the soil in a finely-disseminated form. The intimate penetration by roots and humus insures a deep, inherent fertility and gives the soil a fine crumb structure and permeability regardless of the parent rock. Grasses assimilate great quantities of nutrients, especially calcium, and they return large amounts of the nutrients to the soil. As the grass decays, the efficient rooting system re-assimilates the nutrients, thus maintaining an efficient and rich nutrient cycle (Eyre, 1968).

Microclimates of prairie soils differ from those of the forest. More rapid evaporation by wind and sun takes place in grasslands than in forests and the rapid transpiration of grasses draws on the soil-water around their roots (Farb, 1959). In North Dakota's wettest season, summer, the soil dries rapidly and moisture usually percolates only to root depth. In western North Dakota the subsoil is almost always dry (Omodt et al., 1968).

The black earth or chernozem soils exist beneath the western edge of the mixed prairie and the prairie grasslands of North Dakota (U.S. Dept. of Agriculture, 1938) (Figure 3). Typically, chernozems are such a deep brown, that they appear black in a freshly-plowed field. Most of this deep brown color is due to organic content (Wells, 1965). When the humus is removed chemically, the inorganic fraction of the chernozem soil appears gray. The universal dark coloration of the chernozem humus has not been explained satisfactorily, but it seems probable that it is due to a combination of the composition of the humus supplied, the high alkalinity of the soil, and the high soil temperatures during the summer. This dark-colored humus is so evenly distributed throughout the chernozem profile that quite small amounts give a misleading impression. The average chernozem has an organic content of eight to 20 percent (Eyre, 1968). More than 16 percent is rare, but chernozems with as little as six percent humus still have the typical "black" coloration. The chernozem soils appear homogeneous up to a depth of six feet in the Red River Valley and they are two to three feet thick beneath the Drift Prairie.

Chernozems are chemically basic, and one of their diagnostic properties is an excess of lime and a pH greater than seven (Soil Survey Staff, 1960). Chernozems develop in arid regions where evaporation and upward movement of soil solutions is greater than is leaching and downward movement of soil water and its solutes. In an arid region, therefore, calcium carbonate and other less soluble salts accumulate in the soil. The soils are basic so that the clay minerals remain stable.

In western North Dakota, beneath the drier areas of mixed prairie, chernozems grade first to dark-brown or chestnut-brown soils and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Explanation

Dark colored soils developed under prairie vegetation
    1. Chernozem soils
    2. Chestnut soils
    3. Solonetz soils

Dark colored soils with poor drainage
    4. Humic-gley and $CaCO_3$ (lime) Solonchak soils

Immature and shallow soils on steep slopes
    5. Regosol and Lithosol soils

Soils on stream bottomlands
    6. Alluvial soils

Figure 3. Generalized soil map of North Dakota. Adapted from Ableiter, et al., 1960.

finally, farther west in Montana, to brown soils. The chestnut-brown soils are closely related to the chernozems. They owe their paler coloration merely to the fact that they contain, on the average, only three to five percent organic material. This is because, in the drier climate, the annual production of vegetable matter per unit area is reduced. The brown soils are even poorer in organic matter and quite often contain no more than one percent humus. The actual depth of true soil also decreases with increasing aridity and the horizon of lime accumulation thickens and occurs at progressively shallower depths. There is also a general tendency for the pH to increase (become more alkaline) with increasing aridity. In other respects, the chestnut-brown and brown soils of western areas are similar to the chernozems of eastern North Dakota.

Even though North Dakota's soils have not generally undergone extensive erosion, certainly not to the extent of those in Indiana, Ohio and other eastern states, virgin prairie remnants on North Dakota's four Indian reservations commonly have several more inches of top soil than surrounding cultivated areas. This would indicate that several inches of topsoil have eroded away since the introduction of farming.

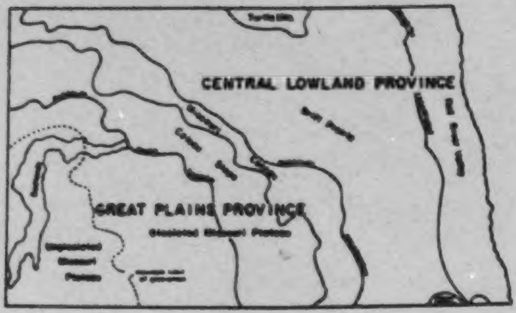
Landscape of North Dakota

Two strikingly different types of landscapes are found in North Dakota. The erosional forces of wind and running water have carved the landforms over much of the southwestern part of the state whereas, over most of the remainder of the state, the landscape is mainly the result of the deposition of materials by the glaciers and their melt water about 13,000 years ago.

Unglaciated Region

The Missouri Plateau encompasses the land to the south and west of the Missouri River as well as a small strip of land 20 to 50 miles wide, north and east of the river (Figure 4). Most of the rock and sediment of the Missouri Plateau ranges in age from Late Cretaceous through Paleocene, 110 million years old to 65 million years old. Scattered patches of Eocene to Miocene sediments, 60 million to 15 million years old, are found in some parts of this region (Carlson, 1969). Streams flowing east during the time the Rocky Mountains were forming during Late Cretaceous and Tertiary time deposited sediment found over the Missouri Plateau today (Bluemle and Jacob, 1973). Outcrops of these sand and clay deposits are now exposed in river valleys and in areas of badlands topography. Thin, discontinuous glacial sediment mantles older rock in some areas close to the Missouri River. The discontinuous glacial veneer on parts of the Missouri Plateau consists of occasional boulders and thin deposits of till (Carlson, 1973). The pre-Wisconsinan glaciers advanced over this area so long ago that erosive forces have eradicated most of their sediments (Bluemle, 1971a).

The Missouri Plateau is a carved landscape with well-developed valleys, undulating uplands with occasional buttes, and large hills. These sculptured landforms are on a much larger scale than north and east of the river. Well-cemented sandstone and limestone beds on the Missouri Plateau resisted erosive forces which removed silt and clay layers. The more resistant sandstone and limestone deposits remain



LEGEND

CENTRAL LOWLAND PROVINCE

Drift Prairie: Rolling glaciated landscape.

Turtle Mountains: Hummocky glaciated landscape that resulted from large-scale glacial stagnation.

Prairie Coteau: Hummocky glaciated landscape that resulted from large-scale glacial stagnation.

Red River Valley: Flat plain resulting from sedimentation on the floor of Glacial Lake Agassiz.

Pembina Escarpment: Steep, glacially-modified escarpment that marks the boundary between the Drift Prairie and the Red River Valley.

GREAT PLAINS PROVINCE

Unglaciated Missouri Plateau: Rolling to hilly, erosional landscape except in badlands area.

Badlands: Rugged, deeply eroded area adjacent to the Little Missouri River.

Glaciated Missouri Plateau: Rolling to hilly, erosional landscape with some evidence of glaciation, especially on the Coteau Slope.

Coteau Slope: Rolling to hilly landscape east of the Missouri River comprised of both erosional and glacial landforms.

Missouri Coteau: Hummocky glaciated landscape that resulted from large-scale glacial stagnation.

Missouri Escarpment: Steep, glacially-modified escarpment that marks the boundary between the Great Plains and Central Lowland Provinces.

Figure 4. Physiographic map of North Dakota. Adapted from Knudson, 1974.

today and form protective caps for the buttes and ridges of that area. Other erosion-resistant rocks found here are the fire-hardened clay, or natural brick ("scoria") formed at the time adjacent coal veins burned; "pseudo-quartzite" (silicified swamp deposits); strata of snail and clam shells; and layers of petrified wood (Bluemle, 1975a).

Glaciated Region

Areas of Glacial Deposits. A diversity of glacial landforms have been deposited north and east of the Missouri River in North Dakota. In this area hills and valleys are closer together and on a smaller scale than on the Missouri Plateau.

Advancing glaciers plowed and gouged underlying soils and rocks, incorporating much material within themselves, mixing and churning these earth materials and depositing glacial sediment, or till, which in northeastern North Dakota commonly has a clayey matrix that incorporates the larger particles. The type of landforms that result depend on the amount of glacial sediment deposited and the mechanism of deposition. Moderate amounts of deposition from beneath the glacier result in gentle rolling topography with some prairie potholes. This landscape made of till is called ground moraine.

Parallel, streamlined ridges of till known as drumlins are found in areas where, during the last glacial advance, little subglacial deposition took place (Clayton and Moran, 1974). Erosion by the glacier resulted in streamlined ridges parallel to the direction of ice movement. In North Dakota the ridges may be several tens of feet high, a few hundred feet wide, and several miles long. The most striking examples are near Velva. These drumlins show up on aerial photographs with a geometrical precision similar to parallel railroad embankments.

Large blocks of material, such as Blue Mountain in Nelson County, and Sully's Hill in Benson County, were moved by large-scale glacial shearing (Bluemle, 1970). Continued glacial advance after the shearing occurred tended to mask the origin of these shear blocks, but where the glacier stopped advancing soon after moving a large block, a hill remained "down ice" of a related depression. These hill-depression relationships are striking on air photos. Hill-depression combinations are numerous in central North Dakota near Harvey, and in the Fort Totten area.

At times the glacier melted back at the same speed it was advancing. Where this happened, the glacial sediment that was deposited at the ice margin resulted in hilly end moraines, which usually are several miles wide and from ten to a hundred miles in length, depending on the length of the margin of the glacier at that point in time. Many of the hilly areas on the Drift Prairie (Figure 4) are end moraines.

The Missouri Coteau (Figure 4), extending from the northwest corner to south-central North Dakota, and the Turtle Mountains in north-central North Dakota, have the most rugged topography of glacial origin in the state. Both are areas of lakes and sloughs with interior drainage. The Turtle Mountains are wooded, due to greater precipitation, whereas the Missouri Coteau is predominantly grassland.

Prior to glaciation, the Missouri Coteau was an upland bordered on the north and east by the Missouri Escarpment. The Turtle Mountains were a large mesa. When the glacier flowed over these areas, the ice was forced upward, resulting in resistance and stress. Internal breaking took place within the flowing glacier as it advanced over the escarpments (Clayton, 1967). Material was carried upward from beneath the ice along cracks in the ice and deposited on top of the ice, which already covered the uplands. As a result, a thick layer of glacial sediment accumulated on the ice of the Turtle Mountains and Missouri Coteau. This deposit served as added insulation for the underlying ice so that it took several thousand years longer for the ice in these two areas to melt than in the rest of North Dakota (Clayton, 1962). The slumping and sliding of debris, as the buried ice melted, formed a dead ice moraine. This is the hilly surface with many potholes and lakes and unintegrated drainage which we see today on the Coteau or in the Turtle Mountains.

Areas of Melt Water Deposits. The large volumes of water associated with glaciation were the result of a higher rate of precipitation, a cooler climate with relatively little evaporation, and melting glacial ice. This run-off developed a distinct topography. Ridges of gravel and sand (eskers) follow the routes of the glacial rivers that deposited them in cracks in the glaciers. They may be over a hundred feet high, several hundred feet wide, and several miles long. The Dahlen Esker is associated with an "esker swarm" in the region of Fordville and Dahlen in Grand Forks County (Kume, 1966). Eskers are the inverted channels of sub- or intra-glacial channels. Their meanderings may be traced and closely resemble those of a modern river.

Broad, flat plains of sand and gravel were deposited by water running from the melting glacier and by rainfall. Outwash gravel and sand that was deposited on stagnant ice slumped into an irregular surface when the ice finally melted (Clayton, 1962). Some of these sand deposits have blown into dunes. In dry years, these dunes still shift, unless they are stabilized by vegetation.

Flat plains lie today in areas once flooded by lakes of glacial melt water. Sediments of clay, silt, and sand were deposited in the lakes. Boulders and wave-washed surfaces border the lake plains. Beach ridges of gravel and sand and wave-cut scarps, which formed along the shore of Lake Agassiz, indicate the various levels of the lake. These beaches are hundreds of miles long and consist of from 5 to 25 feet of wave-washed sediment.

Northwest-southeast trending grooves on the floor of glacial lake Agassiz indicate that during the last year the lake was in existence in North Dakota, icebergs in the lake were driven by the prevailing winds and left grooves of about twelve inches relief on the floor of the lake (Clayton et al., 1965). These grooves show up well on air photos of areas from Fargo, North Dakota to Gimle, Manitoba.

Large rivers flowing into glacial lakes deposited sandy deltas similar to the Mississippi delta which is now being formed in the Gulf of Mexico. Today we see the thick sand deltas of the Pembina and Sheyenne Rivers where they entered glacial Lake Agassiz.

Drainage Pattern Effects on North Dakota Landscape. Southwest of the Missouri River the drainage pattern is similar to that prior to glaciation. Before glaciation the main rivers in that region, the Cannonball, Heart, and Knife, all flowed northeastward. They were diverted southward by the edge of the glacier thus forming the Missouri River Valley (Bluemle, 1972).

Glacial sediments now bury pre-glacial valleys east of the Missouri River. The valleys we see today in the glaciated portion of North

Dakota northeast of the Missouri River were formed as routes for glacial melt water. These include the valleys of the James, Sheyenne, Souris, and Maple Rivers. Parts of the Missouri River Valley coincide with the largest of these melt water channels. Streams no longer flow in some of the valleys that were formed by glacial melt water.

Biology: A General Biogeographic and Ecologic Discussion

Introduction

North Dakota was 98 percent grassland and two percent woodland before the introduction of land cultivation by white settlers in the latter part of the nineteenth century (Pasicznyk, 1970). The woodlands have now shrunk to about 400,000 acres, approximately one percent of the state's area. Much of the forested portion of North Dakota was flooded when Garrison Dam was built; a smaller area was flooded by Lake Oahe. Today, approximately 30 percent of North Dakota's woodlands are found in the Turtle Mountains. Smaller amounts of wooded lands occur in the Devils Lake area, Pembina Hills, and Killdeer Mountains, as well as along the major water courses such as the Sheyenne, Missouri, and Red Rivers.

The great grassland biome, or prairie, with its herbaceous plants, dominates most of North Dakota and, in fact, the entire central part of the continent from Mexico to central Canada, a distance of 2,400 miles (Küchler, 1964). The prairie appears monotonous in the general uniformity of its plant cover, the main features of which are an absence of trees, a scarcity of shrubs, a predominance of grass, and a characteristic xeric (dry environment) flora (Weaver, 1968). Neither the geology, soil, or topography contributes substantially to the character of the flora, which is determined almost wholly by the climate (Coupland, 1959).

Prior to settlement, the North Dakota prairie and the associated tree-lined streams supported a variety of animals including bison, wapiti, white-tailed deer, pronghorn, bighorn sheep, black bear, plains grizzly bear, gray wolf, and mountain lion. Moose and caribou were found in the Turtle Mountains. Subterranean (underground) and cursorial (running) animals inhabited the grasslands with arboreal (tree-dwelling) animals in the trees and shrubs along the water courses (Shelford, 1963).

The North American grassland extends eastward to the deciduous and coniferous forests of Minnesota and westward to the foothills of the Rocky Mountains. It is maintained partly by the availability of moisture as in western North Dakota, where the average rainfall is only 13 inches a year, and partly by fire in areas where trees might otherwise survive except for the prairie fires that periodically sweep the area. Tree seedlings have not been able to survive repeated burnouts, whereas the grass always returns in the spring. Animals of the plains have also helped to maintain their own dominant vegetation, for the bison, which were grazers, liked succulent saplings and destroyed potential forest invaders (Yurich, 1972).

Within the prairie, life conditions are severe. The soil is deep and rich, but water commonly is scarce and must satisfy a large number of plants. Water deficiency usually occurs when the air is driest, when the temperatures are high, and when drying winds blow over the prairie. Such a large number of plant species occur that the taller ones shade the shorter ones, protecting them from the heating and drying effects of the sun or, conversely, shading them so much so that at times the seedlings and lower leaves die for lack of food. With a few exceptions, the plants are free of disease regardless of the weather, and they seldom are harmed by high winds or extreme heat. They may be harmed by late spring frosts or they may be stripped of their leaves and battered to the ground by hail, but they are rarely killed.

The problem of an adequate water supply has been solved by the development of deeply-penetrating root systems (Weaver, 1968). The underground plant parts--rhizomes, bulbs, roots--are food storehouses during the period of winter dormancy, and they account for the rapid growth of the prairie plants in the early spring. All dominant prairie plants are perennials, and most secondary ones are perennials as well. Reproduction is largely vegetative, by tillers, rhizomes, and root sprouts. There are only a few seedling survivors (Barnes, 1948). Roots and rhizomes form such a dense network in the sod that most invaders cannot successfully compete with the prairie plants.

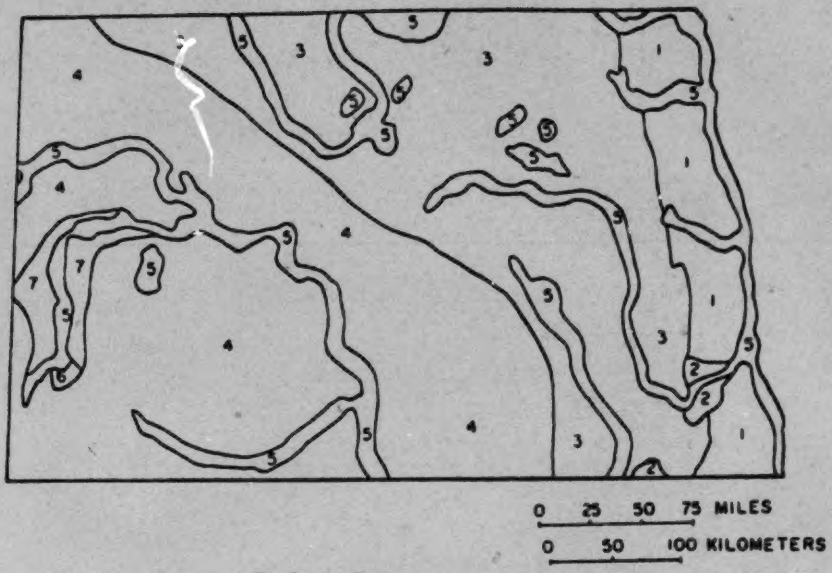
The beauty and quiet calm of the prairie grassland is only apparent for the Great Plains are a place in which competing species each spring renew their struggle for survival. The native species are certainly the fittest plants for the prairie environment for weaker species have been crowded out in the continuing struggle for light, water, and food. Prairie plants fruit sparingly due to the intense competition for sustenance in the prairie environment (Costello, 1969).

Many species, as many as 200 or more in a square mile, can exist together only by sharing the soil at different levels, by obtaining light at different heights, and by making maximum demands for water, nutrients, and light at different seasons of the year (Weaver, 1968). Legumes add nitrogen to the soil. The mat-formers and other species growing close to the ground further reduce water loss by covering the surface of the soil, living in an atmosphere that is much better supplied with moisture than are the windswept plants above them. Light is absorbed at many levels; the near-vertical leaves of the dominant grasses permit light to filter between them as the sun moves across the sky. Fluctuations in temperature of both soil and air are much less in prairie than in cropland, humidity is consistently higher, and evaporation is decreased. The prairie plants' demands for water and light increase more gradually and extend over a longer period of time. Less water is lost by runoff or by surface evaporation and prairie plants generally withstand drought well (Weaver, 1954).

If one walks over the rolling hills and across the intervening valleys, one sees the orderly sequence of the dominance of one species being replaced by that of another recurring again and again, as often as the changes in habitat require it. Many forbs of early spring always remain near the soil surface. Certain species avoid competition with the grasses by producing an elongated stem before they unfold their leaves, thereby assuring an abundance of light. Other species demand leaf space from soil surface to leafy top, which often extends to a greater height than that of the grasses (Hanson and Churchill, 1961).

Natural Habitats in North Dakota

North Dakota can be divided into several major habitat types (Figure 5), each of which is characterized by certain types of plants and animals. Even though each habitat has its own characteristic



Explanation

1. Tall grass prairie (Red River Valley)
2. Modified tall grass prairie; areas of broadleaf deciduous trees scattered or in groups (eastern North Dakota)
3. Medium tall to tall transition grassland (central North Dakota)
4. Mixed prairie; short to medium tall grassland (western North Dakota)
5. Broadleaf deciduous woodland (Turtle Mountains, Killdeer Mountains, Fort Totten area, and other restricted areas including river bottomland)
6. Evergreen woodland (southwestern North Dakota)
7. Sparse grassland on badlands (western North Dakota)
8. Hardwood draws (throughout North Dakota; not identified on map)
9. Prairie potholes (throughout glaciated part of North Dakota; not identified on map)

Figure 5. Major habitats of North Dakota. The habitats listed have characteristic native vegetation and, to some extent, they also have characteristic animal life. Adapted from Küchler, 1964.

plant and animal life, considerable overlap occurs and some species of plants and animals are found in all the habitats. In addition to the habitats shown on Figure 5, North Dakota has thousands of hardwood draws, natural sloughs, ponds, and small lakes, which are found throughout the state. In some instances, such as on Sully's Hill near Fort Totten, "islands" typical of one habitat occur deep within or surrounded by another habitat. Due to its northern latitude and to its less diversified topography, which tends to minimize diversity of habitats, North Dakota has fewer plants and animal species than many other states. Approximately 100 genera and about 1,200 plant species are found in North Dakota. Probably no plant species is found exclusively in the state (Stevens, 1963).

Herbs, which include grasses and forbs, dominate the grassland community. Sedges have much the same community and habitat relations as the short grasses (Johnson and Nichols, 1970). Such grasses as junegrass, blue grama, side-oats grama, hairy grama, needle-and-thread, green needlegrass, sheep fescue, little bluestem, and buffalo grass and such animals as the bison, pronghorn, badger, jackrabbit, and fox give unity to the grassland biome.

Tall Grass Prairie. The tall grass prairie (habitat 1 on Figure 5) corresponds to the Red River Valley in eastern North Dakota (Figure 4). This is a flat plain that resulted from sedimentation on the bottom of the Glacial Lake Agassiz. Humic-gley and Solonchak soils are most common in areas of tall grass prairie in North Dakota (Figure 3) (Omodt et al., 1968). Such soils form under grass or sedge vegetation in grassland areas in poorly-drained areas. They usually occur in flat, low areas (Odell, 1960).

The tall grass prairie, where grasses once grew from three to six feet or more in height, was composed mainly of big bluestem, little bluestem, Indian grass, porcupine grass, green needle grass, switchgrass, prairie dropseed, bearded wheatgrass, and cordgrass. Nearly all areas that were once tall grass prairie have now been cultivated. Few stands of native tall grass prairie exist in North Dakota today (Wanek and Burgess, 1965).

Modified Tall Grass Prairie. In certain parts of eastern North Dakota, the tall grass prairie is modified by the addition of areas of broadleaf, dedicuous trees (habitat 2 on Figure 5). Such areas of vegetation occur in hilly areas of sand dunes such as the Sheyenne delta in southeastern North Dakota and the Pembina delta in the northeast. Chernozem (black earth) soils are most common in these areas, which are fairly well drained. Chernozem soils tend to form in temperate, sub-humid climates in grasslands areas (Odell, 1960).

Most of the area that corresponds to the tall grass prairie habitats (habitats 1 and 2) receives sufficient moisture to support forests and it is believed the grasslands were maintained by periodic fires, which burned off small trees and shrubs (Kirsch and Kruse, 1972) and bison, which ate the tender saplings (Allen, 1967). The woodland that characterizes habitat 2 may be the result of less intense grazing pressure by the bison, which may have preferred to graze the nearby flatter areas.

Medium Tall to Tall Transition Grassland. The transition grassland (habitat 3) extends westward from the edge of the Red River Valley to the Missouri Escarpment (Figure 4). It corresponds, generally, to the Drift Prairie, which is a rolling landscape of glacial landforms.

The transition grassland vegetation is composed mainly of needle-and-thread, green needlegrass, western wheatgrass, slender wheatgrass, big and little bluestem, blue grama, junegrass, and the introduced Kentucky bluegrass, which thrives along with native grasses throughout the grassland biome. The vegetation is generally typical of the Northern Great Plains and consists of a great complexity of plants.

Before the arrival of the white man, bison occurred in great numbers on the Northern Great Plains and the transition grassland probably furnished a large percentage of the forage used by these animals (Allen, 1967). True grassland habitat is ideal for large herbivores (plant-eating animals). However, with the elimination of the bison, the pronghorn was the only remaining native herbivore. Deer feed in the grassland areas, but they prefer locations near cover.

A considerable number of species of rodents inhabit the transition grasslands. The rodent population provides a reservoir of prey for the various predators such as badgers, coyotes, foxes, hawks, and owls. The transition grassland habitat also provides nesting grounds for waterfowl wherever open water is available.

Mixed Prairie. The mixed prairie, or short to medium tall grassland (habitat 4) extends westward from the Missouri Escarpment into Montana except where it is replaced by river bottomland, badlands, and woodland (Figure 4). It corresponds to the Missouri Coteau and the Missouri Plateau. Chestnut and brown soils dominate the area (Figure 3). They have developed in temperate, semi-arid climates, under mixed mid- and short-grass vegetation (Odell, 1960).

The mixed prairie of western North Dakota is composed of short- and medium-height grass with predominating species being western wheatgrass, needle-and-thread grass, blue grama, threadleaf sedge, and Sandberg bluegrass. Wheatgrass and needle-and-thread grass are of medium height, whereas blue grama, threadleaf sedge, and Sandberg bluegrass are short species. Buffalo grass, a short grass that is abundant farther south, is relatively rare in western North Dakota. In the mixed prairie, grasses commonly occur at two levels. One level is usually one to two feet high and the other is eight inches to a foot high (Shelford, 1963). Western North Dakota is one of the few parts of the United States that still has considerable unbroken, though grazed, mixed-grass prairie (Richard Ellison, U.S. Forest Service, personal communication, October, 1974). Such areas are found on private lands, national grasslands, and tribal lands. As the mixed grasses differ in average height, depending on their species, so their roots grow to different depths, with the shorter grasses normally having shorter roots (Shelford, 1963). Buffaloberry, which is common over the mixed prairie, occurs throughout the state. Its close relative, silverberry, is confined mainly to sandy or gravelly areas in the eastern and northern sections. On the edges of woodlands where moisture is almost sufficient for trees, juneberry and sumac extend into the grassland.

In many places over the mixed prairie, the landscape is rough and the breaks afford forage and shelter for many species of birds and mammals. Deer use the south slopes as winter range where skunkbrush and rabbitbrush are present. Sharptailed grouse depend on native prairie vegetation and usually roost in upland swales and in sheltered shrubs in this habitat.

Broadleaf, Deciduous Woodland. Though part of the great American grassland biome, and lacking in any extensively forested area (woodland covers approximately one percent of the state), North Dakota is the meeting place for three kinds of forest (Stevens, 1963). An extension of the eastern deciduous forest (habitat 5 on Figure 5) encroaches on some of the southeastern North Dakota rivers, the Saskatchewan mixed forest extends southward into the Turtle Mountains, and the western end of the state contains outlying parts of the Rocky Mountain forests (habitat 6 on Figure 5).

The most extensive woodland development in North Dakota is in the Turtle Mountains, around Devils Lake, and in the Killdeer Mountains. The first two of these are glaciated landscapes, the result of widespread glacial stagnation, whereas the Killdeer Mountains consist of two large, wooded mesas that formed as a result of erosion of preglacial sediments. The soils of these regions are mainly Chernozem and Regosol soils in the glaciated areas and Lithosol soils in unglaciated areas such as in the Killdeer Mountains (Figure 3). The landscapes range from steep and hilly to hummocky.

In the forested area of the Turtle Mountains, aspen, balsam poplar, cottonwood, boxelder, green ash and American elm are common. Aspen is especially prominent in the timbered areas of the Turtle Mountains, and some stands of paper birch are also found there. Older forest stands usually include considerable bur oak. The woods around Devils Lake are composed mainly of bur oak, green ash, American elm, and some basswood, which becomes increasingly abundant southward. Aspen, boxelder, paper birch, hackberry, and ironwood are occasionally seen in this timbered region. The narrow, timbered belts along the Red, James, and Sheyenne Rivers contain essentially the same tree species as those found in the Devils Lake region.

The river-bluff hardwood forest extends up the Missouri River from the south (Burgess, Johnson, and Keammerer, 1973). In favorable locations, it can be found all the way to the western end of the state, although ash, elm, boxelder, and bur oak are also common in this region.

Evergreen Woodland. The evergreen woodland (habitat 6) is restricted to unglaciated areas of western North Dakota (Figure 5). It is located mainly on the crests of hills and ridges in uplands and on the steep slopes where the upland breaks into the drainageways. Evergreen woodland habitat occurs most commonly on north-facing slopes where temperature and moisture conditions are more favorable. The soils, mainly Lithosols, are predominantly shallow and loamy, well-drained, and they have developed in material weathered from red scoria. Small areas of shallow, loamy soils developed from sandstone are also included (John Bluemle, North Dakota Geological Survey, personal communication, Nov. 15, 1975b). The surface layer of these soils is a loam from two to 17 inches thick containing scoria fragments. The proportion of coarse fragments increases with depth. In some areas, the scoria substratum is only slightly fractured. In other areas it is weathered into small pieces and is as porous as corase gravel.

The characteristic species is ponderosa pine. It occurs as a dense crown cover on some sites and grades into scattered trees of a savanna next to the grasslands. The dominant vegetation in the understory of ponderosa pine on north-facing slopes consists of wolfberry and creeping cedar. South-facing slopes have a sparse cover of predominantly green needlegrass and side-oats grama. Intermediate slopes have a good cover of predominantly green needlegrass in the understory. Rocky Mountain juniper grows on the steep north and east sides of the buttes in the western North Dakota badlands. It assumes a columnar shape near the burning coal seams near Amidon and in Theodore Roosevelt Park, an adaptation to fumes from the burning lignite (Richard Ellison, U.S. Forest Service, personal communication, October, 1974).

The ponderosa pine of North Dakota's evergreen woodland habitat represents the northeastern extreme of its range. It is probably a post-climax situation in which the prairie has bypassed the coniferous forest, which was once much more extensive (Weaver and Clements, 1938). One small stand of Limber pine, normally found in dry, rocky soil in the mountains to the west of North Dakota, occurs in Slope County.

The evergreen habitat affords shelter from the sun, wind, and storm for various wildlife species. Although wildlife is scarce in the evergreen habitat, it does provide nesting and roosting habitat for certain species of birds. Both mule deer and white-tailed deer browse the area. Predators include the bobcat, golden eagle, great horned owl, and various hawks. The area supports local populations of birds such as the Rocky Mountain bluebird that are not found elsewhere in North Dakota.

Sparse Grassland in Badlands. The badlands areas are found mainly along the Little Missouri River (habitat 7 on Figure 5), although scattered areas of badlands topography occur throughout western North Dakota in any areas where erosion is intense. The habitat is restricted to areas of active erosion and high drainage density. It is characterized by complete dissection; narrow, serrate ridges, steep slopes, cliffs, knobs, pinnacles, and deep, vertical-walled gullies. All of the larger streams in the badlands meander over floodplains that were deposited from material washed from the soft sediments in the upper parts of the drainages. The crests of hills and ridges in the badlands are at the same general level and merge with the mixed prairie habitat (Bluemle, 1975a). Soil development, which consists of Regosols and Lithosols and some Solonetz soils (Figure 3), is limited to the gentler slopes and the bottoms of narrow valleys and draws.

The variability of the plant community composition is related to clay content and salinity of the soils. Erosion rate is related to plant cover. The amount of erosion may be a determining factor in the species of plants occurring in certain places. For example, silverscale grows in nearly bare, saline clayey soil (Stevens, 1963). Suaeda also grows on the sides of eroding clay buttes. Draws between the buttes may be dominated by hardwoods.

The rims of landscape, the breaks, scattered rocks, openings between rocks, buttes, and the brushy draws constitute a variety of habitat for wildlife. This variety of cover, forage, and escape areas make the badlands habitat an important wildlife area even thought it may be relatively unproductive from a vegetative standpoint. The windward slopes of buttes and hills blow free of snow in the winter and provide forage for deer and other herbivores. Areas in the lee of boulders or woody vegetation provide cover for nesting and shelter from storms.

Vegetated buttes are like islands in the prairie. They create an edge effect that is important to wildlife (Costello, 1969). Prevailing winds determine the distribution of moisture in the form of snow and, as the air rises over the buttes, updrafts are created for eagles, buteos, and vultures thereby making it easier for them to hunt.

Hardwood Draws. Thousands of hardwood draws too small to show on Figure 5 occur throughout North Dakota. They constitute an important habitat that is characterized by small hardwood trees and brush which occur as stringers in the grasslands. The hardwood draws occur along the bottoms of intermittent and ephemeral streams, in draws and swales, and in other areas where moisture is collected. In the grasslands, the draws and swales have rounded, sloping sides and they may have no distinct channel. Soils are variable and usually undifferentiated, although sandy alluvial soils are common.

The hardwood draws are dominated by shrubs and trees that may vary from a simple overstory of buffaloberry with an understory of grass and forbs to a complex of woody plants in both the overstory and the understory. Trees and shrubs such as green ash, box elder, buffaloberry, chokecherry, and wild plum are common in the west, whereas silverberry and bur oak are more important in the east.

The hardwood draw habitat is extremely important for certain wildlife species that do well in a mixed cover of trees, shrubs, and grasses. Animals like cottontails thrive in the hardwood draws and certain plants furnish forage for deer and nesting and roosting habitat for birds such as quail, cardinals, catbirds, brown thrashers, prairie warblers, and song sparrows.

Prairie Potholes. Thousands of water-holding depressions known as prairie potholes that range from large open lakes and sloughs through small ponds and wet meadows occur throughout the part of North Dakota that was glaciated. The pothole ponds are ringed with cattails, bulrushes, reeds, and whitetop grass. Such diving birds as the redhead, canvasback, and ruddy duck make their nests on mounds of plant debris over the water. The pothole habitat is also the rearing place for broods of dabbling ducks such as mallards, teal, and pintail, which are hatched in nearby uplands.

Prairie potholes have been called the backbone of duck production in North America. Although the prairie pothole region makes up only 10 percent of the total waterfowl breeding area of this continent, it produces 50 percent of the duck crop in an average year, and more than that in some years (Smith, Stoudt, and Gollop, 1964). The pothole habitat also furnishes water and forage for grasslands wildlife and livestock. When drained, the floors of former potholes provide rich soils for the production of crops.

Some of the best prairie pothole terrain is in the Turtle Mountains and on the Missouri Coteau (Figure 4) where glacial stagnation created hummocky dead-ice moraine, but potholes are common over the Drift Prairie as well. Most prairie potholes formed when blocks of drift-covered stagnant glacial ice melted, causing the overlying sediments to drop down, resulting in a depression. In many cases, the depressions intersect the water table, resulting in a permanent lake. In other cases, however, the water table lies below the bottom of the depression so that the pothole merely acts as a catchment basin, collecting runoff from nearby areas. Studies of surface and ground water movement in the vicinity of potholes indicate that inflow to prairie potholes is largely from precipitation and overland flow (Sloan, 1967).

The kinds and amounts of pothole vegetation are related primarily to the permanence and relative salinity of pothole waters. According to Stewart and Kantrud (1972b), who have made detailed studies of pothole ecology for several years, emergent plants (plants that root in the mud underwater and protrude above the surface of the water) in potholes can be grouped into three distinctive vegetative zones which are called wet-meadow, shallow-marsh, and deep-water marsh zones, based on increasing average water depth. The wet meadow zones are dominated by fine-stemmed grasses or short grasslike plants such as fowl bluegrass, northern reedgrass, wild barley, saltgrass, and Baltic rush (Stewart and Kantrud, 1972b). The shallow-marsh zones are dominated by medium-stemmed grasses and grasslike plants that are intermediate in height compared to plants of the wet-meadow and deep-marsh zones. They include tall mannagrass, giant burreed, slough sedge, Whitetop, sloughgrass, common-spikerush, and common three-square. Plants in the deep-marsh zones, coarser and taller than characteristic plants of other zones, commonly include cattails, river bulrush, hardstem bulrush, and alkali bulrush.

According to Stewart and Kantrud (1972b), the vegetation in the emergent and open-water zones of potholes is related primarily to the salinity of the water. Certain plant species including giant burreed, broadleaf water-plantain, slender bulrush, and variable-leaf pondweed are intolerant of saline conditions and are restricted to the fresher potholes. A limited number of salt-tolerant species including alkali grass, samphire, alkali bulrush, and widgeon-grass, occur commonly in saline potholes. Many species are found in brackish potholes, and a few, such as hardstem bulrush and sago pondweed, reach their best development under these intermediate conditions. The predominant plant associations within the deep-marsh zones are closely related to the salinity. The dominant species in most of these associations are slender or river bulrush in the fresher potholes, cattail or mixtures of cattail and hardstem bulrush in the slight brackish potholes, hardstem bulrush in the moderately brackish potholes, mixtures of hardstem bulrush and alkali bulrush in the brackish potholes and alkali bulrush in the saline potholes.

When a pond is first established, certain pioneer plants colonize its shores and later, its bottom. Through the death and decay of these plants, the soil around and underneath the pond becomes enriched with organic nutrients which allow other plants to appear (Amos, 1967). These plants die and decay; sediment builds up, and still different kinds of plants take root. As sediment accumulates, a pond becomes shallower and smaller. Eventually, there is no open water, only a wet spot in a meadow, and that too, soon fills in and dries.

Pond succession does not occur in any one way. The sequence of events varies according to latitude and altitude (it is much slower in cool, moist areas) and according to many geological factors such as soil type and water source (Amos, 1967). Purely biological factors also influence pond succession. A pond may be affected by decaying plant matter in the water of a stream which feeds it, by pollution, or by the land use practices near the pond (Odum, 1971).

Many of North Dakota's lakes and ponds are shallow and extremely rich in many of the materials necessary to life, such as oxygen, carbon dioxide, and various compounds of nitrogen, calcium, and potassium. Ponds that are rich in these materials are designated as eutrophic ("richly nourishing") and they commonly contain large amounts of vegetable and animal life. When eutrophic lakes freeze over, the total volume of water, especially in the shallow ponds, is reduced and oxygen may become extremely scarce for the abundant organisms in the lake. In North Dakota, the ice cover remains for a long time and snow usually covers the ice. Under these conditions, light penetration and photosynthesis are greatly reduced and great destruction of life occurs. This condition is known as "winter kill." Decomposition of the abundant organic matter in the water and at the bottom further depletes the oxygen supply (Benton and Werner, 1966).

General Discussion of North Dakota Vertebrates

Fishes. Fishes can be loosely defined as water-dwelling, cold-blooded vertebrates that have gills and fins. North Dakota has 21 families of fishes (Table 1), including 48 genera and 98 species (Dotson, 1964). Of these, 14 species have been introduced into the state.

In spite of the recurrent winter-kill problems, fingerlings are reintroduced into many lakes and ponds each spring by the North Dakota Game and Fish Department. Partly as a result of this restocking, but especially because of the richly nourishing water in the lakes and ponds, North Dakota holds the record-size catch for several valuable game fish. Sport fishing has become an important form of recreation in the state. All of the North Dakota Indian Reservations either include or are adjacent to bodies of water that contain large numbers of fish that locally provide important food to the people living there.

Amphibians and Reptiles. Amphibians are cold-blooded vertebrates characterized by a moist, smooth skin (Wheeler and Wheeler, 1966). They are so named because they lay their eggs in water (or very moist places) and most spend at least part of their lives, especially during the larval stage, in water. Some remain in water all their lives. Reptiles are cold-blooded vertebrate animals characterized by their dry, scaly skin. Lizards and snakes compose almost 95 percent of the reptilian species (approximately 3,000 species of lizards, and 2,700

TABLE 1

FISHES FOUND IN NORTH DAKOTA (ADAPTED FROM DOTSON, 1964)

Family	Species
Petromyzontidae (Lampreys)	
	Chestnut lamprey (*Ichthyomyzon castaneus*)
Acipenseridae (Sturgeons)	
	Lake sturgeon (*Acipenser fulvescens*)
	Pallid sturgeon (*Scaphirhynchus albus*)
	Shovelnose sturgeon (*Scaphirhynchus platorynchus*)
Polyodontidae (Paddlefishes)	
	Paddlefish (*Polyodon spathula*)
Lepisosteidae (Gars)	
	Shortnose gar (*Lepisosteus platostomus*)
Clupeidae (Herrings)	
	Gizzard shad (*Dorosoma cepedianum*)
Salmonidae (Trouts, Whitefishes, and Graylings)	
	Rainbow trout (*Salmo gairdneri*)
	Brown trout (*Salmo trutta*)
Hiodontidae (Mooneyes)	
	Goldeye (*Hiodon alosoides*)
	Mooneye (*Hiodon tergisus*)
Umbridae (Mudminnows)	
	Central mudminnow (*Umbra limi*)
Esocidae (Pikes)	
	Northern pike (*Esox lucius*)
	Muskellunge (*Esox masquinongy*)
Cyprinidae (Minnows and Carps)	
	Stoneroller (*Campostoma anomalum*)
	Goldfish (*Carassius auratus*)
	Northern redbelly dace (*Chrosomus eos*)
	Finescale dace (*Chrosomus neogaeus*)
	Carp (*Cyprinus carpio*)
	Brassy minnow (*Hybognathus hankinsoni*)
	Silvery minnow (*Hybognathus nuchalis*)
	Plains minnow (*Hybognathus placitus*)
	Hornyhead chub (*Hybopsis biguttata*)
	Sturgeon chub (*Hybopsis gelida*)
	Flathead chub (*Hybopsis gracilis*)
	Sicklefin chub (*Hybopsis meeki*)

TABLE 1--Continued

Family	Species
Cyprinidae (continued)	
	Lake chub (*Hybopsis plumbea*)
	Silver chub (*Hybopsis storeriana*)
	Golden shiner (*Notemigonus crysoleucas*)
	Pugnose shiner (*Notropis anogenus*)
	Emerald shiner (*Notropis atherinoides*)
	River shiner (*Notropis blennius*)
	Common shiner (*Notropis cornutus*)
	Bigmouth shiner (*Notropis dorsalis*)
	Blackchin shiner (*Notropis heterodon*)
	Blacknose shiner (*Notropis heterolepis*)
	Spottail shiner (*Notropis hudsonius*)
	Plains shiner (*Notropis percobromus*)
	Rosyface shiner (*Notropis rubellus*)
	Spotfin shiner (*Notropis spilopterus*)
	Sand shiner (*Notropis stramineus*)
	Bluntnose minnow (*Pimephales notatus*)
	Fathead minnow (*Pimephales promelas*)
	Blacknose dace (*Rhinichthys atratulus*)
	Longnose dace (*Rhinichthys cataractae*)
	Creek chub (*Semotilus atromaculatus*)
	Pearl dace (*Semotilus margarita*)
Catostomidae (Suckers)	
	River carpsucker (*Carpiodes carpio*)
	Quillback (*Carpiodes cyprinus*)
	Longnose sucker (*Catostomus catostomus*)
	White sucker (*Catostomus commersoni*)
	Blue sucker (*Cycleptus elongatus*)
	Lake chubsucker (*Erimyzon sucetta*)
	Smallmouth buffalo (*Ictiobus bubalus*)
	Bigmouth buffalo (*Ictiobus cyprinellus*)
	Black buffalo (*Ictiobus niger*)
	Silver redhorse (*Moxostoma anisurum*)
	Northern redhorse (*Moxostoma macrolepidotum*)
	Greater redhorse (*Moxostoma valenciennesi*)
Ictaluridae (Freshwater catfishes)	
	Black bullhead (*Ictalurus melas*)
	Yellow bullhead (*Ictalurus natalis*)
	Brown bullhead (*Ictalurus nebulosus*)
	Channel catfish (*Ictalurus punctatus*)
	Stonecat (*Noturus flavus*)
	Tadpole madtom (*Noturus gyrinus*)
	Flathead catfish (*Pylodictis olivaris*)

TABLE 1--Continued

Family	Species
Cyprinodontidae (Killifishes)	
	Banded killifish (*Fundulus diaphanus*)
	Plains topminnow (*Fundulus sciadicus*)
Gadidae (Codfishes)	
	Burbot (*Lota lota*)
Gasterosteidae (Sticklebacks)	
	Brook stickleback (*Eucalia inconstans*)
Percopsidae (Trout-perches)	
	Trout-perch (*Percopsis omiscomaycus*)
Aphredoderidae (Pirate perches)	
	Pirate perch (*Aphredoderus sayanus*)
Serranidae (Sea basses)	
	White bass (*Roccus chrysops*)
Centrarchidae (Sunfishes)	
	Rockbass (*Ambloplites rupestris*)
	Sacramento perch (*Archoplites interruptus*)
	Green sunfish (*Lepomis cyanellus*)
	Pumpkinseed (*Lepomis gibbosus*)
	Orangespotted sunfish (*Lepomis humilis*)
	Bluegill (*Lepomis macrochirus*)
	Smallmouth bass (*Micropterus dolomieui*)
	Largemouth bass (*Micropterus salmoides*)
	White crappie (*Pomoxis annularis*)
	Black crappie (*Pomoxis nigromaculatus*)
Percidae (Perches)	
	Iowa darter (*Etheostoma exile*)
	Johnny darter (*Etheostoma nigrum*)
	Yellow perch (*Perca flavescens*)
	Logperch (*Percina caprodes*)
	Blackside darter (*Percina maculata*)
	Sauger (*Stizostedion canadense*)
	Walleye (*Stizostedion vitreum*)
Sciaenidae (Drums)	
	Freshwater drum (*Aplodinotus grunniens*)

species of snakes are found in the world today) (Oliver, 1955).

Most reptiles are tropical in distribution, preferring warmer climates than that of North Dakota. Lizards and snakes occur farther north and south than do the other groups; for example, the red-sided garter snake can be found as far north as the Northwest Territories in Canada (Oliver, 1955).

A total of 14 species of reptiles and 11 species of amphibians are found in North Dakota (Table 2) (Wheeler and Wheeler, 1966). Of these reptiles and amphibians, eight species live in both woodland and grassland. Three are characteristic of woodlands and 12 are restricted to grasslands. North Dakota's reptiles and amphibians are predominantly a southern fauna; that is, most of them are more widely distributed south of the state than north of it. This is what one would expect of cold-blooded animals in the center of the continent.

North Dakota's fauna of reptiles and amphibians is considerably smaller than the numbers present in surrounding states, but comparable to those of nearby Canadian provinces. For example, Minnesota has 45 species (Breckenridge, 1944); South Dakota has 40 (Wheeler and Wheeler, 1966). The differences result from both temperature and precipitation. The average annual temperature is about 12°F lower in northern North Dakota than in southern South Dakota. In the same distance, the number of amphibian species decreases by eight percent whereas the reptiles decrease by 50 percent (Wheeler and Wheeler, 1966).

The effect of rainfall on species distribution and density is seen by comparing North Dakota and northern Minnesota. The average annual rainfall decreases from about 30 inches in northeastern Minnesota to 20 inches in the Red River Valley and 13 inches at the Montana

TABLE 2

AMPHIBIANS AND REPTILES FOUND IN NORTH DAKOTA (ADAPTED FROM WHEELER AND WHEELER, 1966)

Animal

- Class Amphibia
  - Order Caudata (salamanders)
    - Mudpuppy (*Necturus maculosus*)
    - Tiger Salamander (*Ambystoma tigrinum*)
  - Order Salientia (frogs and toads)
    - Plains Spadefoot (*Scaphiopus bombifrons*)
    - American Toad (*Bufo americanus*)
    - Great Plains Toad (*Bufo cognatus*)
    - Dakota Toad (*Bufo hemiophrys*)
    - Rocky Mountain Toad (*Bufo woodhousei*)
    - Gray Tree Frog (*Hyla versicolor*)
    - Chorus Frog (*Pseudacris nigrita*)
    - Leopard Frog (*Rana pipiens*)
    - Wood Frog (*Rana sylvatica*)
- Class Reptilia
  - Order Chelonia (turtles)
    - Snapping Turtle (*Chelydra serpentina*)
    - Painted Turtle (*Chrysemys picta*)
    - Smooth, Soft-shelled Turtle (*Trionyx muticus*)
  - Order Squamata Suborder Lacertilia (lizards)
    - Sagebrush Lizard (*Sceloporus graciosus*)
    - Short-horned Lizard (*Phrynosoma douglassi*)
    - Prairie Skink (*Eumeces septentrionalis*)
  - Order Squamata Suborder Serpentes (snakes)
    - Family Colubridae (non-poisonous snakes)
      - Red-bellied Snake (*Storeria occipitomaculata*)
      - Plains Garter Snake (*Thamnophis radix*)
      - Red-sided Garter Snake (*Thamnophis sirtalis*)
      - Western Hog-nosed Snake (*Heterodon nasicus*)
      - Racer (*Coluber constrictor*)
      - Smooth Green Snake (*Opheodrys vernalis*)
      - Bull Snake (*Pituophis melanoleucus*)
    - Family Crotalidae (poisonous snakes)
      - Prairie Rattlesnake (*Crotalus viridis*)

state line (Jensen, 1974). From the Red River Valley to western North Dakota, the number of amphibians decreases by 27 percent, whereas the number of reptiles remains the same (Wheeler and Wheeler, 1966). A moisture decrease affects amphibians more than reptiles, whereas a decrease in average annual temperature is more unfavorable to reptiles than to amphibians (Oliver, 1955).

The direct effect on man of North Dakota's reptiles and amphibians is slight. Mudpuppies, frogs, and some turtles are edible. Snapping turtles are important as scavengers. Bull snakes and rattlesnakes help to control rodents, and frogs and toads aid in the control of insect pests. The only venomous North Dakota species is the prairie rattlesnake (Wheeler and Wheeler, 1966).

Birds. Birds are warm-blooded vertebrates that have feathers and forelimbs modified to wings. Although not all birds are capable of flight, all those native to North Dakota are. Until recently, it was thought that birds evolved from a dinosaur-like ancestor in Jurassic time, about 150 million years ago. This ancestor, Archaeopteryx (or a similar bird-like reptile), was half reptile, but feathered. Recent theories hold that dinosaurs were warm-blooded animals and the birds are their direct descendants, simply a branch of the dinosaurs which did not become extinct at the end of Cretaceous time as did the larger dinosaurs (Bakker, 1975).

Of the 8,600 species of birds on the earth today, about 1,780 live and breed on the North American continent (Robbins, Bruun, and Zim, 1966). According to Stewart and Kantrud (1972a), about 180 species of birds breed in North Dakota. Almost 200 additional species migrate through the state or visit it occasionally and, according to

Stewart (1971), 358 different species of birds have been recorded from North Dakota.

Stewart and Kantrud conducted statistical studies of North Dakota's breeding birds and found that the state has an average of 368 pairs per square mile or a total bird population of about 52 million during the breeding season. The most numerous bird in North Dakota is the horned lark, followed by the chestnut-collared longspur, red-winged blackbird, and western meadowlark. These four species comprise 36 percent of the total bird population. The next ten species, in order of decreasing numbers, are the lark bunting, savannah sparrow, brown-headed cowbird, clay-colored sparrow, American coot, blue-winged teal, grasshopper sparrow, mourning dove, mallard, boblink, and vesper sparrow (Stewart and Kantrud, 1972a). These ten species comprise 32 percent of the total breeding bird population of the state.

The greatest variety of birds in North Dakota occurs in the northeastern part of the state (except the Agassiz lake plain) that includes the Turtle Mountains and Devils Lake areas (Stewart and Kantrud, 1972a). Eighty-six species are found in this area. The Agassiz lake plain has the fewest bird species--only 47. This apparently is because the area is more intensively farmed than other parts of the state so that much natural habitat has been destroyed.

Birds typical of the grassland environment are most numerous in North Dakota, both in numbers of species and total numbers. The second most productive environment is the wetlands, where waterfowl and shore birds are abundant. Woodland birds are not common in North Dakota. The North Dakota birds of the woodlands sing from perches in trees, whereas many grassland birds sing on the wing.

The spring and summer skies of North Dakota are filled with the songs of horned lark, bobolink, chestnut-collared longspur, lark sparrow, meadowlark, lark bunting, Sprague's pipit, and the nighthawk. Whereas 53 percent of the grassland birds breed on the ground, only 20 percent of forest birds breed in ground-constructed nests (Shelford, 1963).

Mammals. The mammals are distinguished from the other animal groups in that they are warm-blooded, and maintain a fairly constant temperature; they have a four-chambered heart and a highly-developed nervous system; their bodies are more or less covered with hair; and the female has mammary glands for nourishing the young with milk. Six orders of mammals are found in North Dakota (Table 3). They are the Insectivora (insect-eating mammals), Chiroptera (winged mammals), Lagomorpha (rabbit-like mammals), Rodentia (gnawing mammals), Carnivora (flesh-eating mammals) and Artiodactyla (even-hoofed animals) (Bailey, 1926).

The order Insectivora is represented in North Dakota by the moles and shrews, which are small, somewhat primitive animals with pointed noses and feet adapted for burrowing. They spend most of their lives in underground burrows. The order Chiroptera, the winged mammals, are represented by seven species of bats.

The rabbit-like animals, the order Lagomorpha, includes the hares and the rabbits. These animals are similar to the rodents except for their teeth. Members of this order have four upper incisors rather than a single pair as do the rodents. Members of the order Rodentia (rodents) have teeth that are adapted for gnawing. They have a chisel-like pair of incisors that continue to grow as long as the animal lives; gnawing keeps the surface worn back. The

TABLE 3

MAMMALS FOUND IN NORTH DAKOTA (ADAPTED FROM BURT AND GROSSENHEIDER, 1964, AND COLLINS, 1959)

Order Marsupialia
- Opossum (*Didelphis marsupialis*)

Order Insectivora
- Star-nosed Mole (*Condylura cristata*)
- Merriam Shrew (*Sorex merriami*)
- Masked Shrew (*Sorex cinereus*)
- Water Shrew (*Sorex palustris*)
- Arctic Shrew (*Sorex arcticus*)
- Shorttail Shrew (*Blarina brevicauda*)
- Pygmy Shrew (*Microsorex hoyi*)

Order Chiroptera
- Little Brown Bat (*Myotis lucifugus*)
- Keen Bat (*Myotis keenii*)
- Silver-haired Bat (*Lasionycteris noctivagans*)
- Small-footed Bat (*Myotis subulatus*)
- Big Brown Bat (*Eptesicus fuscus*)
- Red Bat (*Lasiurus borealis*)
- Hoary Bat (*Lasiurus cinereus*)
- Long-eared Bat (*Myotis evotis*)

Order Lagomorpha
- Snowshoe Hare (*Lepus americanus*)
- White-tailed Jack Rabbit (*Lepus townsendii*)
- Eastern Cottontail (*Sylvilagus floridanus*)
- Mountain Cottontail (*Sylvilagus nuttalli*)
- Desert Cottontail (*Sylvilagus auduboni*)

Order Rodentia
- Beaver family (Castoridae)
  - Beaver (*Castor canadensis*)

- Squirrel family (Sciuridae)
  - Woodchuck (*Marmota monax*)
  - Eastern Chipmunk (*Tamias striatus*)
  - Least Chipmunk (*Eutamias minimus*)
  - Northern Flying Squirrel (*Glaucomys sabrinus*)
  - Blacktail Prairie Dog (*Cynomys ludovicianus*)
  - Richardson Ground Squirrel (*Citellus richardsonii*)
  - Franklin Ground Squirrel (*Citellus franklinii*)
  - Thirteen-lined Ground Squirrel (*Citellus tridemlineatus*)
  - Eastern Gray Squirrel (*Sciurus carolinensis*)
  - Eastern Fox Squirrel (*Sciurus niger*)
  - Red Squirrel (*Tamiasciurus hudsonicus*)

TABLE 3--Continued

Order Rodentia (continued)

- Pocket gopher family (Geomyidae)
  - Northern Pocket Gopher (*Thomomys talpoides*)
  - Plains Pocket Gopher (*Geomys bursarius*)

- Pocket mice and kangaroo rat family (Heteromyidae)
  - Ord Kangaroo Rat (*Dipodomys ordi*)
  - Plains Pocket Mouse (*Perognathus flavescens*)
  - Wyoming Pocket Mouse (*Perognathus fasciatus*)
  - Hispid Pocket Mouse (*Perognathus hispidus*)

- Cricetid family (Cricetidae)
  - Bushy-tail Woodrat (*Neotoma cinerea*)
  - Northern Grasshopper Mouse (*Onychomys leucogaster*)
  - Deer Mouse (*Peromyscus maniculatus*)
  - Western Harvest Mouse (*Reithrodontomys megalotis*)
  - Muskrat (*Ondatra zibethica*)
  - Boreal Redback Vole (*Clethrionomys gapperi*)
  - Meadow Vole (*Microtus pennsylvanicus*)
  - Prairie Vole (*Microtus ochrogaster*)
  - Sagebrush Vole (*Lagurus curtatus*)

- House rats and mice (Muridae) Old world rats and mice
  - Norway Rat (*Rattus norvegicus*)
  - House Mouse (*Mus musculus*)

- Porcupine family (Erethizontidae)
  - Porcupine (*Erithizon dorsatum*)

Order Carnivora

- Dog and fox family (Canidae)
  - Gray Fox (*Urocyon cinereoargentius*)
  - Red Fox (*Vulpes fulva*)
  - Swift Fox (*Vulpes velox*)
  - Timber Wolf (*Canis lupus*)
  - Coyote (*Canis latrans*)

- Raccoon family (Procyonidae)
  - Raccoon (*Procyon lotor*)

- Weasel and skunk family (Mustelidae)
  - Stripped Skunk (*Mephitis mephitis*)
  - Spotted Skunk (*Spilogale putorius*)
  - Badger (*Taxidea tasus*)
  - Mink (*Mustela vison*)
  - Longtail Weasel (*Mustela frenata*)
  - Shortail Weasel (*Mustela erminea*)

TABLE 3--Continued

Order Carnivora (continued)
Least Weasel (*Mustela rixosa*)
River Otter (*Lutra canadensis*)
Black-footed Ferret (*Mustela nigripes*)
Fisher (*Martes pennanti*)
Marten (*Martes americana*)

Cat Family (Felidae)
Canada Lynx (*Lynx canadensis*)
Bobcat (*Lynx rufus*)
Mountain Lion (*Felix concolor*)

Order Artiodactyla
Elk, deer, and moose family (Cervidae)
Elk (*Cervus canadensis*)
Whitetail Deer (*Odocoileus virgineanus*)
Mule Deer (*Odocoileus hemionus*)
Moose (*Alces alces*)

Pronghorn family (Antilocapridae)
Pronghorn (*Antilocapra americana*)

Hollow-horned ruminant family (Bovidae)
Bison (*Bison bison*)
Bighorn Sheep (*Ovis canadensis*)

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rodents are the largest order of mammals, in both numbers of species and individuals (Bailey, 1926). They include the mice, squirrels, chipmunks, pocket gopher, beaver, woodchuck, muskrat, and porcupine.

The most characteristic burrowing rodent of the grasslands is the black-tailed prairie dog. Prairie dogs feed on both grasses and forbs of various kinds and their disturbance of the sod promotes the growth of annual invaders, plants that grow best on bare soil. Prairie dogs carry subsoil up and spread it on the surface, where it contributes to the enrichment of soils. The deep layers of loosened soil are enriched and fertilized with deposits of vegetation, droppings, and topsoil.

At one time, prairie dogs were extremely abundant on the prairies. One "town" in Texas at the turn of the century was estimated to cover 25,000 square miles and contain 400 million of the animals (Allen, 1967). Literally billions of prairie dogs inhabited the grasslands as recently as the last century, but intensive extermination campaigns by man now have reduced the great prairie-dog population to the members of a few scattered colonies.

The flesh-eating mammals, the order Carnivora, are a varied group that includes four families in North Dakota. All are adapted for living mainly on flesh by having small incisor teeth and large, projecting canine teeth. Most animals of this order have a well-developed sense of smell, which enables them to follow their prey.

The even-hoofed mammals, members of the order Artiodactyla, support their bodies on the third and fourth toes; other toes have been reduced in size or lost. They have strong molar teeth with broad surfaces for grinding the plant food on which they live.

Speed, keen eyesight, strength and endurance are some of the adaptive mechanisms that have evolved among various grassland mammals. The pronghorn graze prairie knolls, constantly alert for enemies and able to quickly escape danger. The pronghorn can travel 40 miles an hour at a steady pace and up to 54 miles per hour for short distances (Allen, 1967). The bison with his blizzard-defying pelt and great strength and endurance can outlast most storms and overpower most enemies.

The gregariousness of grassland wildlife is exemplified by the pronghorn, bison, and prairie dog. Herds of up to 400 pronghorn have

have been reported and I have counted 50 in a herd. Bison were said to herd in groups of from 100,000 to 2,000,000 before the great hunts of the last century (Dary, 1974). Before white settlement, it was estimated there were about 15,000,000 pronghorn on the northern plains. Whitetail jackrabbits were so abundant, and in parts of North Dakota they are still common, that their trails were easily traced across the plains (Bailey, 1926).

Man's Influence on the Biology

The plains Indian utilized the bison and other game, the herbaceous plants, and the woody shrubs. The Mandan Indians took advantage of the relatively moist Missouri River Valley in central North Dakota where a sufficiently long growing season allowed them to raise long-season crops, such as corn. This resulted in the establishment of farming, rather than a nomadic culture (Lehmer, 1970).

Most of the non-Indian immigrants to North Dakota were initially ignorant of the grassland biome. They did not understand how to use its richness without upsetting its natural balance and they were not prepared to cope with the continental climate of the region (Robinson, 1966). Their needs for food, shelter and clothing often led them to imitate habits learned in the eastern United States or Europe and to exploit areas not suited for sustaining large numbers of people. Their tools could not cut the prairie sod and their grain would not ripen during the short growing season of most of the State. Their domestic livestock thrived on the nutritious prairie grasses, but severe winters took their toll on cattle, which require shelter whereas bison do not (Dary, 1974).

With the introduction of the steel plow and seed that would mature at North Dakota's latitude, men were able to profitably farm the land north and east of the Missouri River. The overall appearance of North Dakota changed as most of the eastern part of the state went into cultivation. Three-fourths of the land south and west of the Missouri River is still grassland, but it has been grazed in most places so that the ratio of original species to introduced ones is reduced due to the selective foraging of cattle in places where the range has been overgrazed. In these areas, natural grassland productivity has been reduced and the modern plains have vegetation consisting mainly of the more hardy species (Weaver, 1968).

Early Man in North Dakota

The history of man on the North American continent is complex, nebulous, and highly controversial, as numerous theories of the origin of man in North America have been proposed. No attempt will be made here to discuss all, or even many, of these theories, but rather, this will be a brief, simplified discussion of man in the Great Plains.

Many methods of sorting the cultural manifestations of early North American man have been proposed, but I prefer Stephenson's (1965) simple organization of subdividing his habitation into three broad headings. These are: (1) the Paleo-Indian Stage, which begins with the first inhabitation of the area and ends with the general extinction of the big game animals, the disappearance of the well-made lanceolate projectile points, and a general economic dependence on small game; (2) the Archaic Stage, which begins at the end of the Paleo-Indian Stage and ends with the development of agriculture, ceramics, the bow and arrow, and the establishment of a semi-sedentary village life; and (3) the Sedentary Stage, which begins at the end of the Archaic Stage and ends with the domination of the area by European immigrants.

Paleo-Indian Stage

There are indications that early man immigrated to the North American continent as long as 40,000 to 60,000 years ago (Krieger, 1964). The origin of such ancient men as those postulated by Krieger is not clear however, because they appear to have had none of the Mongoloid racial characteristics common to the American Indians and modern Mongoloid Asiatic people. If they immigrated at that time, they probably became extinct on the North American continent in a relatively short time.

Authorities such as Martin (1973) maintain that paleolithic man first crossed the Bering land bridge in large numbers in late Wisconsinan time, at the end of the Pleistocene Epoch, about 11,300 years ago. These paleolithic people are known as Clovis man (Martin, 1973; Bronowski, 1965). Clovis man migrated southward as soon as an ice-free corridor opened between the Rocky Mountains in Alberta and the continental glacier to the east. The southward movement of these paleolithic people was rapid and, according to Martin's theory, they soon attained a density sufficient to kill and bring to extinction much of the large game of the continent. Although this theory is by no means universally accepted, it is true that the disappearance of native American mammoths, mastodons, ground sloths, horses, and camels coincided closely with the end of the glaciation, a time when conditions should have been improving for these animals (Hoffman and Jones, 1970). The most certain radiocarbon dates related to such extinctions narrow the time of extinction down to 11,300 B.P. ± 100 years (B.P. means "before present"), and the corridor in western Canada between the western, or Cordilleran, ice sheet and the continental, or Laurentide ice sheet, opened about 11,500 B.P. This was the first opening in 10,000 years and it offered Clovis man, a highly skilled hunter, access to the Great Plains (Martin, 1973).

Apparently the population of the Clovis man rose rapidly as he moved southward. Clovis man reached North Dakota about 11,300 years ago and the tip of South America by 11,500 B.P. (Martin, 1973). Their population was always greatest close to the game supply of large animals and they moved southward with the big game.

It is possible that the extinctions of large animals at the end of the glacial epoch may have been due to factors other than hunting pressures, changes in climate that were unfavorable to the animals, for example (Martin and Wright, 1967). Whatever the reason for the large game extinctions, the climate did tend to moderate at about the same time. The warmer and drier climate resulted in the spread of prairie environment into North Dakota. With the removal of many of the large animals and the spread of grasslands over the plains, an ideal habitat was created for the bison, previously a woodland animal. It underwent its own "population explosion" as it moved into the grassland niche emptied by earlier extinctions.

The bison that first filled the niche left by the extinction of other big-game animals was larger than the modern bison and has itself become extinct although it probably remained and was hunted until about 8,000 years ago. The hunters from this period (11,000 to 8,000 B.P.), Folsom man, were probably small groups of people who moved from place to place in search of animal herds (Klein, 1974).

Generally then, the Paleo-Indian Stage in the Northern Great Plains begins with the earliest immigrants into the area. These people brought with them a poorly-known inventory of crude tools at a time when the now-extinct Wisconsinan large game was abundant (perhaps as long as 40,000 to 60,000 years ago).

The Paleo-Indian Stage includes what is known as the Llano Culture, which had a highly-developed stone working technology (Krieger, 1964), at a time when elephants and extinct species of bison were still being extensively hunted and at a date that can be safely placed at at least 12,000 years ago (Stephenson, 1965). It also includes a somewhat more sophisticated Lindenmeier Culture of approximately 10,000 years ago when the elephants were extinct, but certain now-extinct bison were still an item of diet (Krieger, 1964) and the Plano Culture of 10,000 to 8,000 years ago, marked by unfluted, lanceolate points and continued hunting of the same bison species as those hunted by members of the Lindenmeier Culture. The Paleo-Indian Stage ended with the general disappearance of the large lanceolate points and the general extinction of the big game animals, about 7,000 to 8,000 years ago (Stephenson, 1965).

Archaic Stage

The activities of early men on the northern plains from 8,000 to 3,000 years ago are not well known. They appear to have practiced big-game hunting, but eventually they gave way to a series of hunting people not primarily concerned with large game, but instead utilizing whatever animal forms that were available. These people were succeeded by another series of hunters and gatherers to whom vegetable foods were of increased importance. Studies of arrowheads, mounds, and teepee rings indicate that man has lived in North Dakota for at least 6,000 years and probably for 11,000 years (Wedel, 1962).

The Archaic Stage can be considered to have begun with the introduction of corner-notched projectile points at a time when the general ecological situation over the Great Plains had shifted and man's economy could no longer depend on the large game animals (Wedel, 1964). It corresponds generally with Altithermal time (see discussion of Ancient Climate). The people lived on small animals such as rodents, birds, and fish as well as on vegetable products.

Mayer-Oakes (1959) suggested that the Archaic Stage on the Great Plains developed out of an acculturation between the last remnants of the big-game hunters and the westward expansion of an already-established eastern Archaic culture. In any event, it is reasonable to suppose that the Great Plains in this time of hotter, drier climate than before, underwent a demise of the big-game-hunting economy and the development of a new way of life (Stephenson, 1965).

Sedentary Stage

At some still unknown time, the archaic cultures of the Great Plains gradually began to be replaced by a more elaborate and more complex way of life. Larger groups of people began living together in communities of gradually increasing stability, with semi-permanent dwelling structures. Increased attention was placed upon the burial of the dead. Experiments with the planting of crops gradually developed into an economic dependence upon agriculture. Pottery containers became a household necessity, and the bow and arrow, as indicated by small side-notched projectile points, replaced the atlatl and dart as a weapon of warfare and the hunt.

Along the middle Missouri River in North and South Dakota, the earliest of the sedentary cultures have been grouped into a Middle Missouri tradition (Lehmer, 1970). Included in this tradition are the sub-groups referred to as the Monroe, Anderson, Over, Thomas Riggs, and Huff foci. The sites are identified primarily on the basis of distinctive pottery and villages of semi-subterranean, long-rectangular houses, sometimes situated in rows within the village. Some of the villages were fortified with a distinctive rectangular palisade, surrounded by a dry moat, and strengthened by regularly spaced, loop bastions. The villages are usually large, especially the later ones of the tradition, with as many as a hundred houses in a single village. Carbon-14 and dendrochronological dates suggest a time span of 1,300-500 years ago for this tradition.

A final development in the prehistoric Sedentary cultures of the Plains is represented along the middle Missouri River by villages of circular earth-lodges, with or without fortifications. The circular, earth-covered house, with four central roof-support posts, a central fireplace, and covered entryway was a very different type of dwelling from the earlier rectangular house. When fortifications were present in these villages, they too were of a different style, being oval in pattern, with bastions the exception rather than the rule. The villages ranged in size from a few houses in some sites to as many as 200 or 300 houses in others. There were a great many of these villages. Some were compact clusters of houses, others were widely dispersed settlements.

Pottery styles changed too, as did some of the other artifacts, but changes were by no means as dramatic as were the changes of house and village pattern, and there is no indication that the basic economy changed at all (Stephenson, 1965). Dated sites indicate that the circular-house villages made their appearance in North Dakota about 500 to 600 years ago and that the earliest of these were contemporaneous with the latest of the villages with long-rectangular houses. Whether this represents a new people moving into the Plains or a development out of the earlier cultural pattern is not clear, but the first possibility appears to be more probable, as no developmental sequence between the two has been demonstrated (Lehmer, 1970). In any event, this was a time of heavy population density along the middle Missouri River Valley, a density that must have been comparable to the white population of the area sixty years ago. With numerous minor variations, the circular earth-lodge villages dominated the area well into the historic period, ultimately becoming the villages of the people known historically as the Mandan, Arikara, and Hidatsa. The last such village of these three tribes, known as Like-a-Fishhook Village, in central North Dakota, was abandoned about a century ago.

Historic Man

Indian tribes have inhabited the area now known as North Dakota for hundreds of years. Land claimed by Indian tribes did not have boundaries in the contemporary non-Indian understanding of boundary lines for the Indian believed that land and natural resources were the common property of all the people as is the air one breathes. Each tribe claimed certain areas for its homes and for hunt purposes. The boundaries of land claimed by individual tribes were not constant, and the history of the Indians in the Northern Plains contains many references to tribes driving their neighbors from certain areas and being themselves eventually driven from that area by more powerful people. In addition to forced migrations, many tribes moved to new locations seeking better hunting (Eiseley, 1955).

The Turtle Mountains were inhabited by roving bands of Indians for at least three thousand years (Mayer-Oakes, 1967). Mayer-Oakes stated that mound builders passed through the area two to three thousand years ago and mounds excavated at Rock Lake, Manitoba date back 1,600 years. These mounds may owe their origin to activities of Assiniboine Indians or their forebears. One of these groups of mound builders was the progenitor of the Algonquian people of which the Chippewa and Cree are branches. Another group led to the Siouan tribes of which the Hidatsa are a branch. The Chippewa were first established in the Turtle Mountains about the time the first white men visited the area (Schulenberg, 1956).

The earliest reference I know of to a definite band of Indian people in North Dakota goes back to Verendrye, about 1738. At that time, a band of about 200 Chippewa, known as "Medinakwadshiwininwak" was established in the Turtle Mountains (Gorneau, 1973).

The name "Chippewa" is a popular adaptation of the name "Ojibway," one of the largest Algonquian tribes whose former range was on both shores of Lakes Huron and Superior. They were living at Sault Ste. Marie in 1642 and were at that time at war with the people west of them (Tefft, 1964). They obtained firearms from the traders at an early date and began moving westward, although they did not obtain a foothold west of Lake Superior until 1736.

Eventually, they drove most of the Sioux from Minnesota and, after 1800, moved into northern and eastern North Dakota in company with the fur traders who were exploiting that region (Denig, 1961).

When white traders intermarried with the Chippewa and Cree, they created a mixed-blood race or "Metis." At first the mixture contained largely French and Indian blood, but soon Irish, Scotch, and Swiss were added. The Metis developed their own culture, midway between Indian and white, became buffalo hunters, and were apt linguists. Pierre Bottineau, scout and guide, was a Pembina Metis (Sealey et al., 1975).

The Mandan Indians apparently were the first agricultural people to arrive in North Dakota. The Arikara came next and then the Hidatsa, who were known also as Minitori. North Dakota has been occupied by agricultural Indians for at least a thousand years (Lehmer, 1971).

Although the Mandan are of Siouan stock, they differ from the Sioux in their mode of life and material culture. The early history of the Mandan tribe appears to be sketchy and, in some instances, entirely mythological. According to their traditions, they lived in an easterly region, in the vicinity of a large lake or near the sea. They may have moved northwestward across the Mississippi valley, and there is reason to believe that they first reached the Missouri River near the mouth of the White Earth River in South Dakota (Will and Spinden, 1906). From this point, they moved northward by successive stages. During this gradual movement up the Missouri, they constructed many earthlodge villages and occupied some of them for long periods of time. It is not known when the first Mandan Indians appeared on the land that is now North Dakota, but there is reason to believe it was at least 500 years ago and it may have been as long ago as 1,500 years (Brown, 1973).

In 1738, the Mandans were living in the vicinity of the Heart River in Burleigh and Morton Counties in North Dakota. In 1804, Lewis and Clark found them living in the vicinity of the Knife River, although enemy attacks and disease had reduced their numbers substantially (Holloway, 1974). In 1832-1833, Catlin and Maximilian visited them and left an elaborate account of their life and culture (Crawford, 1931). Chardon's journal describes the smallpox epidemic of 1837 which almost decimated the Mandans at Fort Clark. Those who survived smallpox joined with the Hidatsa and moved to the Fort Berthold Reservation, where the Arikara later joined them (Abel, 1932).

The Arikara Indians are of Caddoan stock and are closely related to the Skidi Pawnee of Nebraska. This group of Caddoan people, originating in the south, gradually worked their way northward up the Missouri River. The French traders found the Arikara located on the Cheyenne River in South Dakota in 1770, but in 1804 Lewis and Clark found them living in the vicinity of the Grand River in South Dakota (Thwaites, 1959).

The Arikara were friendly to the white settlers but a group of fur traders under the leadership of Ashley in 1822 attacked them. The Arikara were blamed for the skirmish and in 1823 General Leavenworth drove them from their village. They were not settled in a permanent village until they were moved to the Fort Clark village in 1838, and finally to the Fort Berthold village in 1862, where they became allied with the Mandan and Hidatsa. They are presently living on the Fort Berthold Indian Reservation.

The Hidatsa, also known as the Gros Ventre, are of Siouan stock and, according to their traditions, came to the Missouri River from the northeast and joined the Mandan in the Heart River area (Matthews, 1969). There is some question concerning the origin of the Hidatsa culture, but it is believed by many ethnologists that they adopted the culture of the Mandan (Wilson, 1917). Since the time both tribes occupied the area in the vicinity of the Heart River, they have been allies, and their lives and cultures have been identical in many respects. The Hidatsa are now living on the Fort Berthold Reservation.

The Cheyenne and Sioux Indians migrated westward into North Dakota, the Cheyenne ahead of the Sioux, from Minnesota about 1700 A.D., ahead of the advancing white settlers (Brown, 1973). The Sioux, also known as the Dakota, were the largest and most dominant of the plains Indian tribes. They consisted of three major groups: the Santee, Teton, and Yanktonai, distinguishable by their dialects, Dakota for the Santee, Lakota for the Teton, and Nakota for the Yankton. All came from the east, traveling by rivers, and were known as "canoe Indians" when they reached the Minnesota country.

The Tetons, who comprised more than half the Dakota tribes, were the first to abandon their birch-bark lodges and move onto the plains to live in buffalo-hide tipis (Hassrick, 1967). The Santee, sometimes known as woodland Sioux, came late to the plains, being driven from their Minnesota lands after 1860. At their peak, there were probably about 200,000 plains Indians and the Sioux probably accounted for one sixth of the total (Brown, 1973).

Father Hennepin stated that the Teton Dakota were living near the falls of St. Anthony, Minnesota in 1680. Although they preceded the Yanktonai in their westward journey, very few of them had crossed to the west side of the Missouri River before 1750. In 1804, Lewis and Clark found them near the Teton and Cheyenne Rivers in South Dakota. They gradually spread westward, and eventually claimed western South Dakota, southwestern North Dakota, and parts of Wyoming, Montana, and Nebraska. The Teton Sioux Indians included the following tribes: Oglala, Brule, Blackfeet, Miniconjou, Sans Arc, Two Kettle, and Hunkpapa. Each of these bands had their own chiefs and operated as separate units, although they did unite to attack their hereditary enemies, and against the encroachment of the white. Many well-known chiefs or leaders were members of the Teton Sioux; they included Red Cloud, Crazy Horse, Gall, and Sitting Bull (Hassrick, 1967).

The Yanktonai, one of the largest branches of the Dakota or Siouan race, were originally a forest people living in Minnesota near Mille Lac and adjacent areas. They were driven from there by the Chippewa, whose early contact with white traders provided them with firearms, against which the Sioux could not cope. Lewis and Clark stated that the Yanktonai were found on the headwaters of the Sioux, the James and the Red Rivers (Thwaites, 1959). In 1855, Warren located them between the James and Missouri Rivers and north to Devils Lake. Apparently the Yanktonai were not confined to this area, as Verendrye mentioned that the Assiniboin were afraid of attacks by the Sioux while enroute to the Mandan villages. In 1797, Alexander Henry had difficulty in persuading the Chippewa Indians, who accompanied him, to go beyond the mouth of the Park River, because they feared an attack by the Yanktonai (Nelson, 1946).

Although they were bitter enemies of the Assiniboin and Chippewa, the Yanktonai were, on the whole, peaceable towards the whites and did not participate in the Minnesota Uprising or the Indian Wars of 1876. Most of the Yanktonai were assigned to the Standing Rock Reservation in North and South Dakota. The Sisseton and Wahpeton Sioux, who were representatives of the Santee Dakota, may have been found in the extreme southeastern part of the state in limited numbers. Comparatively few, however, were found in North Dakota until they were driven from Minnesota after the uprising of 1862 (Utely, 1963). Dakota Indians belonging to the Santee group were assigned to a reservation at Fort Totten, North Dakota.

Generally, the pre-Columbus tribes farmed the plains where there was sufficient moisture and a long enough growing season and they travelled little. They hunted buffalo, often by driving the herd over a cliff. Their only domesticated animal was the dog. When tribes moved from one place to another, they used their dogs as beast of burden (Farb, 1968).

The way of life of the agriculturally-oriented Indians appears to have changed drastically (among other things they changed their housing and pottery styles) probably due to the arrival of new people or tribes about 1500 A.D., but this is not certain. Circular lodges, of the type that can be seen in reconstructed form near Mandan, North Dakota at the Slant Village, date to the post-1500 A.D. date (Lehmer, 1971).

It is probable that long before the coming of the Europeans and the horse, man in North Dakota had learned to survive and function in the draws around the water holes of the prairies. He probably left the higher areas in cold or dry seasons, and followed the movements of the bison as they were driven by storms and drought. The harsh climate and the repeated immigrations and movements of new "tribes" over the plains resulted in a group of people who were biologically quite diverse, probably more so than in other parts of North America (Brown, 1973).

Before they had the horse, most of the tribes referred to as plains Indians lived on the fringes of the Great Plains or along rivers, dwelling in permanent villages. They did some hunting, but they also grew corn, melons, squash, pumpkins, beans, tobacco, and other native crops. They made pottery and they wove fabrics. Typical semi-agricultural plains Indians were tribes belonging to the Caddoan-speaking confederation, which included the Wichitas and Pawnees and extended from the Arikaras of North Dakota to the Wacos of Texas (Will and Spinden, 1906).

The plains Indians lived on the diet of the vegetables already mentioned along with some meat. They pulped and dried wild fruit for preservation during the winter, mixing some with dried buffalo meat to make pemmican. This diet was a good one and the Indians were generally in better physical condition and considerably larger than the white immigrants (Farb, 1968).

Until they had the horse, hunting the bison was difficult for the plains Indians. One method of entrapment involved making piles of rocks and logs in a V-shape, the wide end of the V being a good grazing ground while the narrow end led into a natural or man-made corral where the captured bison could be slain as they milled around. This method was more common on the northern plains where large numbers of glacial erratics were available to construct the V. Corrals of this type were also known as "parks." (The Park River in eastern North Dakota takes its name from the fact that the Indians constructed buffalo-entrapment parks along the river (Williams, 1966).

The introduction of the horse to the plains Indians was extremely important. In a way, the change was comparable to what mechanization of industry and agriculture did to free industrial workers from long hours of labor (Brown, 1973). With horses available to carry their travois and their tipis, tribes no longer had to wait for migrating buffalo to come to them. They could follow the seasonal movements of the herds. The semi-nomads became nomads, which brought them into more frequent contact with other tribes. It led to an exchange of goods, foods, crafts, and knowledge. It resulted in an era of prosperity for the plains Indians which lasted less than a century. During this period, most tribes had adequate food, shelter, and clothing and there was leisure time to practice the arts, enjoy the natural world of sky, earth, water, plants, and animals. In that time the plains Indians became poets, and their contempotary speeches have survived to read like poetry (McLuhan, 1971).

CHAPTER IV

NATURAL SCIENCE OF THE NORTH DAKOTA INDIAN RESERVATIONS

Standing Rock Sioux Indian Reservation

Geologic Features

Eight geologic formations are exposed on the Standing Rock Indian Reservation (Carlson, 1969). The oldest rock unit exposed on the reservation is the Pierre Formation cropping out along the Oahe Reservoir adjacent to South Dakota (Plate 1). The Pierre Formation is a medium-dark to light-gray marine shale of Cretaceous age, 80 to 100 million years old. It grades upward into the Fox Hills Formation.

The shale of the Pierre Formation forms a rolling, dissected topography with rather smooth slopes, a result of its proximity to the Missouri River where erosion is vigorous. In South Dakota, where the Pierre Formation is widely exposed away from the river, the landscape is flatter. Soils developed on the shale tend to be infertile, but this is not a major consideration on the Standing Rock Reservation as the small area of sediments of the Pierre Formation there has topography too rolling to farm.

The Fox Hills Formation, a marine shale and sandstone also of late Cretaceous age, is exposed over the eastern part of the reservation at relatively low elevations (Plate 1). Near its base, the Fox Hills Formation is highly fossiliferous (Feldmann, 1972) but fossils are found throughout the formation. The fossils occur in concretions near the contact with the Pierre Formation and in cemented sandstone ledges. The clam Tancredia americana and the crustacean burrow Ophiomorpha are abundant in a small coulee along State Highway 24 between Fort Yates and Selfridge (SW¼ sec. 36, T. 130 N., R. 81 W.). The landscape developed on the Fox Hills Formation is gently rolling except near the larger valleys, where it is strongly rolling. Much of the area covered by the Fox Hills Formation gives rise to good cropland. Some buttes in the area are capped by sandstone of the Fox Hills Formation.

The late Cretaceous Hell Creek Formation is primarily a continental deposit consisting of sandstone, mudstone, silstone, carbonaceous shale, and lignite. It is widely exposed over the higher areas in the eastern part of the reservation and in the lower areas along the Cannonball River in the western part of the reservation. Particularly prominent exposures of Hell Creek sediments occur in badlands areas along State Highway 6 in sec. 28, T. 132 N., R. 82 W. and in sec. 16, T. 131 N., R. 82 W. (Frye, 1969). The contact between the Fox Hills and Hell Creek Formations is exposed in several places, e.g., Crow Ghost Cemetery west of Solen; in sec. 32, T. 132 N., R. 80 W.; and sec. 35, T. 132 N., R. 80 W. One can usually find fossil bone fragments during a few hours search over any of the Hell Creek badlands areas on the Standing Rock Indian Reservation. Dinosaur bones are more common farther southwest, however.

Badlands topography is common in many areas of the Hell Creek Formation. Slopes are usually steep and barren, and soil development is poor. The soils which do develop in flat areas are commonly infertile, in marked contrast to those on the Fox Hills Formation.

The Paleocene Cannonball Formation is a marine deposit of alternating layers of sandstone, siltstone, shale, and limestone concretions. It overlies the Hell Creek Formation except in places where continental deposits of the Ludlow Formation, which interfingers with the Cannonball Formation, lie above the Hell Creek Formation (Plate 1). The Cannonball Formation occurs in the Selfridge area, the Porcupine hills, the Pamplin hills, and over the western part of the reservation. Prominent exposures of Cannonball shale occur about a mile north of Selfridge along Highway 6. The landscape developed on the Cannonball Formation is gently rolling to flat in most places on the Standing Rock Reservation. Soils are fair to good and the cropland is generally fertile.

The Tongue River Formation, a continental formation of Paleocene age, is exposed at the extreme western end of the Standing Rock Reservation. It is not well exposed anywhere in that area, but to the north, in Grant County, good exposures of Tongue River sandstone are common. On the reservation, the Tongue River Formation consists of a sandstone directly overlying the Cannonball Formation. This sandstone is overlain by interbedded sandstone, claystone, siltstone, shale, limestone lenses, and lignite. The landscape developed on the Tongue River Formation on the reservation is gently rolling with gentle slopes. Farther west, along the Little Missouri River, badlands are developed in the Tongue River Formation. The generally fertile soils found on the Tongue River Formation in the reservation result in good cropland.

Pleistocene glacial deposits of the Coleharbor Group occur in a few scattered areas of northeastern Sioux County. The glacial deposits consist of thin patches of till on the tops of a few hills; this sediment consists of particles of all sizes, ranging from clay to boulders. Particles of shale are common in the glacial sediment and the shale is largely responsible for the high clay content. Glacial erratics are also found scattered over the eastern half of the reservation, but the western part of the area was never glaciated. Glacial deposits were probably once more extensive than they now are and have been removed by erosion.

The flat area near Fort Yates consists of Missouri River terrace sand and gravel which is overlain in places by lake sediment. The lake sediment, which can be seen in a coulee cut about two miles southwest of Fort Yates (sec. 23, T. 130 N., R. 30 W.), was apparently deposited in a proglacial lake that formed when the preglacial drainage was blocked by glacial ice. The drainage was probably northward at that time (Bluemle, 1972).

In a few places in the western part of the reservation, areas of apparently patterned ground, the result of permafrost activity, can be seen on air photos (Plate 1). It is almost impossible to recognize these on the ground.

Holocene river alluvium and windblown silt and sand, which occur in several places, are part of the Walsh Formation. Alluvium is present on the Cannonball River floodplain and on the smaller floodplains, such as those of Porcupine Creek and Battle Creek. Amounts of windblown material are negligible in most places, and only a few deposits are shown (Plate 1). Several blowout holes occur over the western part of the reservation, mainly in the sandstone of the Tongue River Formation. Wind lineations are apparent on air photos in the same area. They indicate that the prevailing winds during the recent geologic past have been from the northwest. Dunes can be seen in T. 131 N., R. 80 W., along the highway in the valley of Porcupine Creek.

Geologic History

The Pierre, Fox Hills, and Hell Creek Formations, all of late Cretaceous age, apparently represent a sequence of beds that were all deposited at about the same time. Even though the Fox Hills Formation overlies the Pierre, and the Hell Creek Formation overlies the Fox Hills, it is possible that the three formations are essentially contemporaneous with one another, although not in the same location. The following explanation is a logical one for the stratigraphic relationships among the three formations (Arthur F. Jacob, formerly of the University of North Dakota Geology Department, personal communication, Nov. 13, 1974).

In general, the marine Pierre Formation shale was deposited in deep water, some distance off shore. The Fox Hills Formation, also marine, was deposited in somewhat shallower water. The Hell Creek Formation was deposited by rivers and streams; that is, it is continental (deposited on land). The sea gradually filled with sediment due to the erosion of material from the newly-formed Rocky Mountains to the west, and it became shallower as sandstone of the Fox Hills Formation was deposited. With continued filling of the sea, the sediments eventually built up to sea level and Hell Creek sediments were deposited over the area, much as material is being deposited on the Mississippi Delta today.

The three formations are distinct and reflect conditions that existed in three different environments, but the Pierre Shale was being deposited in eastern Sioux County at the same time the Fox Hills sandstone was being deposited in central Sioux County, and Hell Creek sediments were being deposited in western Sioux County, a total distance of about 40 miles from a deep-water environment to an above-water, deltaic environment. Therefore, even though the Pierre, Fox Hills, and Hell Creek Formations were all deposited about the same time, they owe their differing characteristics to the differing depositional environments in which they were formed, ranging from offshore shales to nearshore sandstone and shale to onshore sandstone. The shore of the sea in which the sediments of the three formations were deposited gradually retreated eastward as the sediments filled the sea.

Studies of fossils, particularly dinosaurs, have shown that the top of the Hell Creek Formation represents the boundary between the Mesozoic and Cenozoic Eras. Dinosaur-bearing Hell Creek Formation strata underlie non-dinosaur-bearing Cannonball and Ludlow Formation strata. The Cannonball sandstone and shale were deposited in a sea that flooded the area in Paleocene time. The Ludlow Formation was probably being deposited farther west at the same time the Cannonball Formation was being deposited in Sioux County. As the sea filled with sediment, the area of Tongue River deposition migrated eastward (Arthur F. Jacob, formerly of the University of North Dakota Geology Department, personal communication, Nov. 13, 1974). If the Sentinel Butte Formation sediments were deposited on top of the Tongue River Formation in Sioux County, they were removed by erosion that took place sometime in the interval between Paleocene and Pleistocene time, a period of about 60 million years, removed these later deposits.

Glaciers that advanced over much of North Dakota during Pleistocene time covered the eastern two-thirds of Sioux County. Immediately prior to the advance of the glaciers, the streams in and near the reservation area drained northeastward, as the Cannonball River does today. The Missouri River did not yet exist in North Dakota however, so the streams continued to flow northeastward, eventually reaching Hudson Bay (Bluemle, 1972).

With glaciation, the northeast-draining streams were blocked and diverted southward, resulting in the formation of the Missouri River Valley. Glacial ice that covered all but the southwestern part of Sioux County left scattered till deposits, but erosion since then has removed most of these deposits, leaving only boulders in most places. The glaciers that deposited thick sediments east of the Missouri River during the most recent advance of glacial ice did not advance over the Standing Rock Indian Reservation and their deposits are not present in the area.

During the time that has elapsed since North Dakota was glaciated, erosion has modified the land surface somewhat. Erosion was greatest during the drier periods when there was no sod cover to protect the hillslopes. Running water has removed large amounts of sediment from some places in Sioux County. Badlands areas are the most graphic example.

River floodplain deposits, which are important only along the larger streams and rivers such as the Cannonball (the Missouri River floodplain deposits are flooded by Lake Oahe), consist mainly of silt and fine sand with coarser sand in places. These water-laid deposits have been deposited intermittently since the ice age. In sandy areas, wind has blow the sand into dunes.

Vegetation

It is generally possible to subdivide the Standing Rock Indian Reservation into several distinct habitats that are governed primarily by moisture availability. They include (1) the grasslands, which cover most of the area; (2) the wooded areas along the Missouri River, now mainly flooded by Lake Oahe; (3) the draws on the sides of buttes and other small intermittent and ephemeral streams; and (4) scattered, small areas of badlands.

The most widespread habitat on the Standing Rock Indian Reservation is the grasslands, which occur over the undulating and smoother slopes of the reservation. They are characterized by a vegetation that is generally typical of the northern Great Plains. When near climax, the grasslands support a great complexity of plants. The grass species present consist of a mixture of short grasses and midgrasses as well as forbs.

Vegetation typical of the grasslands include blue grama, needle-and-thread grass, green needlegrass, prairie june grass, western wheatgrass, sand dropseed, threadleaf sedge, green sage, long-headed coneflower, blazing star, sandberg bluegrass, thickspike wheatgrass, little bluestem, thimblegrass, yarrow, catsfoot, little sage, white prairie aster, purple coneflower, and blue wild lettuce (Johnson and Nichols, 1970).

Shrubby willows are abundant in wet places, but the most characteristic shrub is buffaloberry, which grows on the drier parts of the flood plains and in the coulees between the hills. Dogwood, juneberry (known also as service berry and Saskatoon berry), and wild roses also are common. Big sagebrush is limited to small areas along the little Missouri River. It usually grows only two or three feet high. Greasewood grows on some buttes and rabbitbrush is common. Creeping red cedar is common on the hills, especially on north slopes (Stevens, 1963).

Usually the higher ground on the grasslands is rather dry and the plants are those of the prairie. However, in slightly lower places, which are moist and well shaded, species such as blue violet, fringed loosestrife, and pink dogbane can be found (Stevens, 1963).

The prairie vegetation varies greatly with relatively slight differences in elevation and soil texture, which affect the amount of moisture the soil retains. A shallow drainage way on a hillside may have different grasses and a deeper green color than the slopes only a few inches higher (Stevens, 1963). The coulees, winding among the hills, have a dense tall growth of grass and many more species of plants than occur in the sparse, short grass on the hills. According to Stevens (1963), Canada anemone, wild lily, prairie dandelion and yellow stargrass are found in the slightly depressed areas along with a variety of grasses such as slender wheatgrass, wild rye, big bluestem, and false redtop. By contrast, the grasses of the ridges are blue grama, needle-and-thread, little bluestem, and prairie junegrass. Examples of other plants common to the ridges are the white prairie aster, fringed sage, and downy painted cup. On the driest, most exposed slopes or tops of hills, one finds white milkwort, threadleaved sedge, gray goldenrod, tufted milkvetch, and moss phlox (Stevens, 1963).

The vegetation of the wooded areas along the Missouri River is composed of cottonwood, Missouri willow and various other woody species native to the area (Johnson, 1971). Cottonwood, the typical tree species, is rarely found elsewhere on the reservation. Green ash, boxelder, buffaloberry, chokecherry, and wild plum also are found, but these are also common in draws, and gulches along intermittent stream courses. The vegetation of the wooded areas may consist of scattered cottonwood trees with a grassy understory or a cottonwood overstory with a dense understory of various woody species with a few Missouri willows in depressions (Johnson, 1971). Other plant species typical of this habitat include the wild rose, western virgin bower, Virginia wild-rye, marsh muhley, wolfberry, skunk bush, poison ivy, plains bluegrass, and western wheatgrass.

The third typical habitat of the reservations, the small valleys or draws, occurs along the bottoms of intermittent and ephemeral streams, in coulees and swales, but in other areas where moisture collects, shrubs and small trees dominate. The composition of this plant community may range from a simple overstory of buffaloberry with an understory of grass and forbs to a complex of woody plants in both the overstory and the understory. The small valleys where this habitat occurs produce a great variety of species because of the favorable moisture conditions, greater snow accumulation, and some modification of the microclimate because of topography and woody plants. Characteristic plants of the habitat include green ash, box elder, buffaloberry, chokecherry, wild plum, western wild rose, wolfberry, Missouri gooseberry, western wheatgrass, red raspberry, round-leaved hawthorn, green needlegrass, wild strawberry, big bluestem, pink wood violet, wild parsley, and lambstongue ragwort (Stevens, 1963).

Badlands occur in only a few places on the Standing Rock Reservation, primarily in association with outcrops of the Hell Creek Formation. Some badlands areas are completely lacking in vegetation and soil development is negligible. A sparse vegetative cover of a few grasses, shrubs, and forbs exists where some soil development has occurred. Existing vegetation is extremely important for controlling erosion and furthermore, the amount of erosion may be a determining factor in governing which plant species occur on certain sites. For example, silverscale grows on nearly bare, saline clay soil. Suaeda also grows on the sides of eroding clay buttes. Draws between the buttes are commonly dominated by hardwoods.

Typical plants found in the badlands environment include rabbitbrush, salt sage, silverscale, spiny saltbrush, saltgrass, western wheatgrass, plains reed grass, Indian ricegrass, long-leaved sage, merigonum, green sage, plains muhly, blue grama, little bluestem, burning bush, tufted milkvetch, creeping cedar, and Rocky Mountain red cedar. The species of plants that occur in the badlands areas of the Standing Rock reservation are similar to those found on sonoran desert types (Küchler, 1964).

The environment one finds on the slopes and near the tops of such hilly areas as the Porcupine Hills and Pamplin Hills on the Standing Rock Indian Reservation is typified by steep, rocky land. It occupies the highest areas because of relatively resistant layers of limestone, sandstone, or pseudoquartzite. The numerous springs, draws, depressions, scattered rocks and openings between rocks provide for a great variety of vegetation, which forms a complex including small trees, shrubs, forbs, and grasses. The variation in slope, exposure, and drainage creates a more diverse assortment of microclimates than the more level land. Most plants found in the other areas also are found in the rocky areas near and on the buttes.

Typical plants include dwarf juniper, wolfberry, ill-scented sumac, buffaloberry, plains reedgrass, needle-and-thread grass, purple coneflower, prickly pear, yucca, creeping cedar, red three-awn, and sideoats grama.

Animal Life

The Standing Rock Indian Reservation can be divided conveniently into several habitats. The wooded areas along the river bottomlands are extremely important to animal life, particularly in the summer, since these areas have both cover and water. Species dependent on water during the dry summer months use these wooded areas extensively. Animals and birds, such as the beaver, white-tailed deer, mule deer, raccoon, red-tailed hawk, black-billed magpie, red-shafted flicker, western wood pewee, Aububon grasshopper mouse, long-tailed weasel, and plains garter snake, are typical of the wooded areas. The scarcity of perennial streams in western North Dakota makes existing streams all the more important. The surface water, especially inlets along Lake Oahe, and the vegetation associated with surface waters, make the river bottomlands an important habitat for many species of animals.

The draws on the sides of buttes are important to wildlife as shelter. Some of the plants growing in these areas provide forage for deer and nesting and roosting habitat for birds. Typical animals include the white-tailed and mule deer, mountain bluebird, sparrow hawk, black-capped chickadee, least chipmunk, and striped skunk. Deer find protection in the draws from summer sun and winter storms. Sharptail grouse rest in trees and shrubs at the heads of the draws, especially in the autumn. Ring-necked pheasants use the brush as nesting cover and many species of birds nest in the shrubs and trees (Miller, 1955).

The grasslands areas, which cover most of the reservation, are the home of such animals as the mule deer, coyote, red fox, sharptail grouse, gray partridge, nighthawk, rock wren, brewers blackbird, northern pocket gopher, pronghorn (at the extreme west end of the reservation), white-tailed jack rabbit, raccoon, black-tailed prairie dog, thirteen-lined ground squirrel, meadow vole, burrowing owl, western meadow lark, horned lark, and mourning dove. Foxes and coyotes commonly build their dens in the rougher areas along the slopes of buttes in grassland areas. Hawks, owls, and other predators hunt the grasslands extensively (Allen, 1967). Deer use south slopes as winter range where skunkbrush and rabbitbrush are common. Sharptail grouse depend on native prairie vegetation and usually roost in upland swales and on sheltered east slopes. Many small birds nest in clumps of grass or under low shrubs. The large populations of the grasslands provide a reservoir of prey for the various predators such as badgers, coyotes, foxes, hawks, and owls. The prairies also provide nesting grounds for waterfowl wherever open water is available (Stewart and Kantrud, 1972b).

The breaks, badlands, buttes, and brushy draws all constitute a variety of habitats. This variety of cover, forage, and escape areas make the badlands an important area even though vegetation is scarce. Typical birds and animals include the golden eagle, red-tailed hawk, prairie falcon, prairie rattlesnake, horned lizard, mule deer, white-tailed jackrabbit, desert cottontail, bobcat, red fox, coyote, horned lark, and badger. Although the climate at times is severe and the terrain often hostile, the isolation of the badlands makes them a valuable wildlife habitat.

Turtle Mountain Indian Reservation

Geologic Features

The entire area of the Turtle Mountain Indian Reservation (Plate 2) is covered by glacial deposits of the Coleharbor Group that range from about 100 feet thick in the southeast to about 300 feet thick in the northwest. Preglacial sediments are not exposed on the reservation (Bluemle, 1971a).

At least seven different landform types, all related to glaciation, occur on the Turtle Mountain Indian Reservation. Ground moraine, consisting mainly of materials that were deposited by melting of relatively clean glacial ice, has rolling relief. Some glacial stagnation features can be seen on aerial photographs of ground moraine areas. Till is the main lithology and a few boulders are found on the surface in areas of ground moraine. Areas of dead-ice moraine coincide with the Turtle Mountain upland. In the Turtle Mountains, the dead-ice moraine ranges from rolling to hilly. Till is the main lithology in the areas of dead-ice moraine, as it is in the ground moraine areas, but scattered patches of gravel and sand are more common in the dead-ice moraine.

An outwash plain occurs in the south-central part of the reservation. In some places the outwash plain forms a flat surface, but in other places, particularly near Belcourt Lake, the surface is rolling with up to 50 feet of relief (Deal, 1971). In these areas, the sand and gravel, which cover the outwash plain, were deposited on top of stagnant glacial ice.

In some places, materials washed and slid down the slope of the escarpment at the edge of the Turtle Mountains. Although most of these materials (sand and gravel with some boulders and till) are fluvial, some of them are colluvial. These deposits range from hilly near the escarpment to nearly flat at the south edge of the reservation.

Narrow, linear ridges of shaley gravel and sand are ice-contact fluvial deposits known as eskers. Most common in the western part of the reservation, the eskers were deposited by melt water streams flowing in tunnels and valleys in the glacial ice. When the ice melted, the gravel and sand that had been deposited in these tunnels and valleys remained as esker ridges.

Most areas of lake deposits are covered mainly by silt and clay, but others are predominantly clay. The lakes in which these deposits accumulated were present on the dead-ice landscape and, as a result, they collapsed when the ice melted. They have rolling relief. The single exception is the lake deposit in Section 1, T. 162 N., R. 70 W. in the extreme northeast corner of the reservation. This lake deposit is flat and was deposited on an area that was not underlain by stagnant glacial ice.

Alluvium, consisting of a mixture of silt, sand, and clay, is present in two small stream valleys on the reservation. The alluvial sediments were deposited by running water since the ice age ended.

Geologic History

The Turtle Mountain area has essentially the same geologic history as the Standing Rock Indian Reservation until about Pliocene time. About 10 million years ago, during the Pliocene Epoch, the area that is now the Turtle Mountains was part of a broad plain that sloped gently to the east. Rivers and streams flowed over the plain from the west, gradually making their way to the area that now is Hudson Bay. Sometime during the Pliocene Epoch, probably between five and 10 million years ago, the rivers and streams began to erode away large amounts of material from Manitoba and North Dakota. It is not known exactly why this cycle of erosion began. Perhaps the area was uplifted by geologic forces so that streams began to cut into the sediments they had been flowing over, or perhaps the climate changed. As sediment was eroded away, new hills and valleys were shaped and, gradually, as the sediments surrounding the Turtle Mountains were carried away to the sea, a large mesa was left standing where the Turtle Mountains are today.

About three million years ago, at the start of the ice age, the climate turned colder and, as snow built up to great depths west of Hudson Bay, glaciers formed and flowed southward, out of Canada into the United States. The climate fluctuated and the glaciers advanced and receded, flowing around and over the Turtle Mountains several times during the Pleistocene Epoch. Finally, about 20,000 years ago, the most recent glacier flowed southward over the Turtle Mountains.

The movement of glacial ice over an obstruction such as the Turtle Mountains causes the ice to become compressed and results in shearing within the glacier. The shearing caused large amounts of rock and sediment, the material over which the glacier was moving, to be incorporated into the ice and the result was a glacier that contained a large amount of debris (Clayton, 1967). As the climate gradually moderated, and the ice age came to a close, the glacier finally stagnated, and several hundred feet of dirty ice remained over the surface of the Turtle Mountains.

In areas surrounding the Turtle Mountains, where there had not been much shearing of material into the glacier, the ice was clean and it simply melted away. While the glacier continued to move over the lower areas around the edge of the Turtle Mountains, it deposited ground moraine in places. However, as the dirty, stagnant ice in the Turtle Mountains melted, the debris it contained gradually became concentrated at the surface of the ice, resulting in an increasingly thick insulating layer that greatly retarded the rate of melting. The glacier stopped moving and stagnated over the Turtle Mountains about 13,000 years ago and, as a result of the layer of insulation built up on top of the stagnant glacier, it was not until about 9,000 years ago that the last ice there melted (Clayton, 1967).

Studies of debris-covered stagnant glacial ice in Alaska have shown that six feet of material on top of the ice is sufficient to almost completely insulate the buried ice (Winters, 1963). In the Turtle Mountains, the cover was several tens of feet thick and even over 100 feet in places. The surfaces of buried, stagnant glaciers are not barren, cold areas. Trees and other vegetation are abundant on debris-covered glaciers in Alaska (Clayton, 1967). In some places, luxuriant plant growth is present on as little as five feet of insulating cover. Lakes that develop on top of the insulating cover contain relatively warm water derived almost entirely from rainfall. The lakes support abundant aquatic life such as fish, clams, and waterfowl and, in surrounding areas, mammals such as mink, muskrat, and beaver are common (Sherrod, 1963). Conditions in the Turtle Mountains while stagnant ice was melting were similar to this.

Vegetation

The Turtle Mountain Indian Reservation has a woodland flora similar to that of western Minnesota or southern Manitoba. O. A. Stevens (1966) suggested 750 as the approximate number of different plant species in that area.

According to Bird (1961) the vegetation of the Turtle Mountains can be considered the ecotone between boreal forest and prairie. Stewart (1971) studied upland vegetation in the Turtle Mountains to gain an insight into the vegetational history and future of the region. He studied 11 forest vegetation stands, three upland vegetation stands, and three island vegetation stands. In the youngest forest stand, aspen was the most abundant species, but some bur oak, green ash and boxelder was also present. In slightly older stands, green ash and paper birch became more common. In still older stands, balsam poplar was dominant. The most common shrub on all but the island stands was beaked hazel. Juneberry was also important in the younger stands, but chokecherry became more important on older stands. Stewart lists 67 species of herbs. Wild sarsaparilla, false lily-of-the-valley, snowberry, strawberry, and beaked hazel were the most important species in all but the island stands. The most important species on the island stands varied from sarsaparilla to wild plum or poison ivy.

Generally, poplars are common throughout the Turtle Mountains, with oak limited to the drier, exposed slopes. Ash is common, but American elm is relatively uncommon. The wetter parts have several species of willow and the woods usually have a dense cover of shrubs including rose, hazel, chokecherry, currant, raspberry, hawthorne, arrowwood, and highbush cranberry, also known as pembina (Burgess and Disrud, 1969).

The undergrowth includes a great variety of herbaceous plants. In many places wild sarsaparilla makes a complete cover. The vetches are abundant. Pink dogbane is common, especially along roadsides or other openings. Ferns are rare, represented mainly by the grape fern. Ostrich fern occurs rarely. Extensive clearing in recent years has caused a decrease of many plants and an increase of others (Disrud, 1968; Scoggan, 1957).

A few high elevations along the south edge of the Turtle Mountains (but not Boundary Butte, which is the highest point) have grassland above the trees. Fescue which occurs in some of these areas becomes a major grass in more northern prairies of Saskatchewan and Alberta (Coupland, 1950).

Potter and Moir (1961) studied the interaction of fire and vegetation in the Turtle Mountains. Coniferous trees, which are not found naturally in the Turtle Mountains today, apparently grew there in the recent past. Pollen analysis of shallow peat deposits show coniferous pollen nearly to the surface. Potter and Moir felt that the current absence of conifers is probably due to frequent fires during intense drought, and subsequent competition with trembling aspen.

Before the arrival of modern man, the dominant influence on the vegetation of the Turtle Mountains appears to have been a combination of climate and fire (Potter and Moir, 1961). When compared to the surrounding prairie, the greater amount of precipitation that falls on the Hills and cooler temperatures there probably account for the presence of a forest. Fire played a major role in the species diversity and age of the vegetation. Since the turn of the century, modern man has played a major role in shaping the landscape of the Turtle Mountains through extensive land clearing, other agricultural practices, and accidental or planned fires.

The Turtle Mountain Indian Reservation has many lakes and ponds, most of which are potholes that formed when blocks of buried, stagnant glacial ice melted at the end of the ice age. Most of the lakes and ponds in the Turtle Mountains are permanent and contain relatively fresh water. A few typical plant species include the bulrushes, cattails, liverworts, duckweed, bladderworts, various aquatic mosses, pondweed, and sedges (Stewart and Kantrud, 1972b).

Other plants typical of the bogs and sloughs of the Turtle Mountain Indian Reservation include joe-pye weed, flat-top aster, and pond lily. Plants such as bugleweed are found in cold boggy springs in the woods (Stevens, 1963).

The lakes and ponds of the reservation are important to waterfowl. The evaporation rate is lower in the wooded areas than in the nearby grasslands (Smith, Stoudt, and Gollop, 1964); hence, the May density of wetlands in the Turtle Mountains may be twice that of the prairie, and by July it may be three times that of the prairie. In an average year almost one third of the prairie wetlands become dry between May and July. In a dry year, over two thirds of the potholes may lose their water.

Animal Life

Most of the animals now found on the Turtle Mountain Indian Reservation have been there since prehistoric times, with the exception of the raccoon, which was not present in the area until about 1900. The fauna of the Turtle Mountain Indian Reservation area is somewhat different from that of much of North Dakota, more adapted to woodlands than prairie, although many of the animals found there do occur in both environments. Until late in the 19th century, bison, elk, moose, and bear were common in the Turtle Mountains. Elk and moose were killed in the area as late as 1887 and bear as late as 1904 (Bailey, 1926).

Today, the larger mammals of the Turtle Mountains still include an occasional moose or elk that may stray into the area. Mule deer and whitetail deer are common. Coyotes are common on the reservation and timber wolves, lynx, and cougar sometimes are seen in the Turtle Mountains. The abundant lakes and ponds in the Turtle Mountains, coupled with the forested terrain, provided an ideal habitat for beaver, which are abundant. Mink also are abundant as are the muskrat, two species of weasel, skunk, swift fox, and red fox. Other mammals include the porcupine, red squirrel, least chipmunk, snowshoe hair, and silver-haired bat (Collins, 1959).

Fifteen species of ducks breed in the Turtle Mountains (Stewart, 1971) and probably as many breed in the Devils Lake area. Eight of these species are dabbling ducks and seven are diving ducks. They include: mallard, blue-winged teal, American widgeon, gadwall, pintail, wood duck, green-winged teal, shoveler, ring-necked duck, canvasback, ruddy duck, bufflehead, redhead, lesser scaup, and common goldeneye.

Common shore birds in the area include several varieties of gulls, the common loon, black tern, double-crested cormorant, merganser, coot, and avocet (Stewart, 1971).

The numerous lakes and ponds over the reservation provide ideal habitat for amphibians such as the tiger salamander, Dakota toad, chorus frog, leopard frog, and wood frog. The western painted turtle is common. Snakes include the red-sided garter snake, plains garter snake, western hog-nosed snake, and smooth green snake (Wheeler and Wheeler, 1966).

Fort Berthold Indian Reservation

Geologic Features

The part of the Fort Berthold Indian Reservation south of Lake Sakakawea is mainly a bedrock surface with scattered areas of glacial drift. North of the lake, glacial deposits predominate and only patches of bedrock occur. The landscape reflects this distribution of sedments; south of the lake, hills and badlands are common, but north of the lake the glaciated topography is undulating to rolling (Clayton, 1970; 1972). Five geologic rock formations occur on the Fort Berthold Indian Reservation. They are the Tongue River, Sentinel Butte, and Golden Valley Formations, which are all bedrock formations, and the glacial deposits of the Coleharbor Group and the postglacial Walsh Formation.

The oldest bedrock exposed on the Fort Berthold Indian Reservation is the Tongue River Formation, which crops out in the northwest part of the area along the reservoir in McKenzie County (Plate 3). The Tongue River Formation is a continental formation of Paloocene age that consists of yellowish silt, clay, sand, lignite, and sandstone. The landscape developed on the Tongue River Formation on the reservation is steeply rolling due to its proximity to the Missouri River Valley. Badlands occur in places.

The Sentinel Butte Formation, also of Paleocene age and also a continental deposit, is widely exposed south of Lake Sakakawea. It occurs in several places north of the lake, mainly adjacent to the Missouri River Valley. The Sentinel Butte Formation consists of yellowish to grayish layers of silt, clay, sand, lignite, orange scoria, and sandstone (Royse, 1967). Along the Missouri and Little Missouri River valleys, badlands that have been carved into the Sentinel Butte Formation expose extensive thicknesses of sediment. Relief in these areas is locally over 250 feet.

Overlying the Sentinel Butte Formation, in a few places south of Lake Sakakawea, is the Golden Valley Formation of Paleocene and Eocene age (Carlson, 1973). It consists of bright-colored layers of siltstone, sandstone, and shale that is kaolinitic in places. The Golden Valley Formation is easily recognized wherever it is exposed as it is brighter than the Tongue River and Sentinel Butte Formation, almost white in some exposures.

The Coleharbor Group covers the northern part of the Fort Berthold Indian Reservation (Bluemle, 1971b). It has been subdivided into five identifiable units that depend on a combination of composition and surface expression. Three of the units essentially have the same composition--glacial till that was deposited directly by glacial ice. In places, the till cover is thin and discontinuous and relief in these areas is developed on bedrock. Wherever the till is thick enough, the relief is a result of the till accumulation itself. Such areas are referred to as either ground moraine or end moraine. Areas of ground moraine are undulating to rolling with relief generally less than 50 feet locally. Ground moraine formed when materials in the ice were deposited by the base of the glacier as it moved over the area. The end moraine was deposited at the edge of the active glacier when its margin stood in that area and the till surface is bouldery.

Areas of sand and gravel were deposited by water flowing from the melting ice. These areas are quite flat and are mainly in valleys. Flat areas of silt and clay were deposited in lakes that formed due to the melting of the glacial ice.

The Walsh Formation consists of silt, clay, and sand that were deposited since the time of the glaciers. Most of the sediment of the Walsh Formation is alluvium (river and stream sediment). Sloughs also contain Walsh sediment, but most of these are so small that no attempt was made to show them on Plate 3.

Geologic History

The Tongue River and Sentinel Butte Formations, both of Paleocene age, represent a sequence of beds that were deposited by east-flowing streams flowing across deltas to shallow seas. Although Sentinel Butte sediment overlies Tongue River sediment, it is possible that the two formations were deposited at essentially the same time, although not at the same location (Arthur F. Jacob, formerly of the University of North Dakota Geology Dept., Nov. 13, 1974). At the same time, the Cannonball Formation was being deposited farther east in deeper water near shore.

In Paleocene time, about 65 million years ago, the area which now is the Fort Berthold Indian Reservation was the site of an inland sea. The Rocky Mountains were being uplifted and, as they rose, they were subjected to erosion. Streams that carried the materials eroded from the mountains flowed eastward toward the sea, depositing these materials along their routes and on deltas that they built into the sea. The deeper-water sediments were mainly the shales and sands of the Cannonball Formation; whereas, near the shore in shallower water to the west, continental sands and silts of the Tongue River Formation were being deposited as deltaic sediments. As the sea gradually filled with sediment, the main location of deposition shifted eastward so that Tongue River sediments were deposited on top of Cannonball sediments and Sentinel Butte sediments were deposited on top of Tongue River sediments. Eventually, the sea was filled and deposition ceased in most places. Golden Valley sediments were deposited in Paleocene and Eocene time in the remaining lakes after the sea had regressed.

Deposition of stream sediment continued after the deposition of the Golden Valley Formation, but the extent of this deposition is not known because only small patches remain. The geologic record from Eocene until Pleistocene time is represented by an unconformity. Before glaciers advanced over the area, streams drained mainly northeastward (Bluemle, 1972). Early glaciations diverted this drainage southeastward, cutting new valleys that were used by both the diverted drainage and by melt water from the glaciers. The largest of these diversion trenches in the area of the Fort Berthold Indian Reservation are the valleys of the Little Missouri and Missouri Rivers.

When the Little Missouri River, which originally flowed north into Canada, was diverted eastward, its new route followed a steeper gradient. This resulted in "rejuvenation" and the cutting of badlands topography on the reservation as well as farther southwestward. Thus, the badlands are an indirect result of glaciation.

Successive advances of the ice reached different limits. The

Van Hook Arm of Lake Sakakawea fills a valley that was cut during an early glaciation. The present route of the Missouri River through the Fort Berthold Indian Reservation was established, however, during the latest glaciation, the Late Wisconsinan.

The glacial deposits south of the Missouri River mainly are the result of relatively early glaciations whereas those exposed in most places north of the river were deposited in Late Wisconsinan time. North of the river, the earlier glacial deposits are buried beneath the most recent glacial deposits.

The Fort Berthold Indian Reservation has undergone essentially the same geologic history since the end of the ice age as has the Standing Rock Reservation. As the area north of Lake Sakakawea has a thicker accumulation of glacial deposits than any part of the Standing Rock Reservation, erosion and weathering have started on a fresh surface whereas the older preglacial deposits of Standing Rock have undergone a continuation of previous weathering processes.

Erosion and weathering of the glacial deposits of the Fort Berthold Reservation have been slight although fertile soils have developed on the glacial deposits. The overall shape of the landscape in glaciated portions of the Fort Berthold Reservation has been modified only slightly since the end of the ice age. Running water has transported some sediment from the hillsides to depressions, but, in most places, drainage has not developed well enough to carry the material away. The few streams that occur in these areas are located mainly in old glacial melt water trenches.

In areas along the Missouri River Valley, burning lignite seams have baked the nearby sediments to natural brick. This process is going on today and it may have been common long before the ice age ended. Some of the natural brick is found in locations that are beneath the water table. Natural brick in these places formed when the climate was drier than today as the lignite had to be above the water table to burn.

Vegetation

The Fort Berthold Indian Reservation can be subdivided into six distinct habitats that are governed primarily by moisture availability. They include (1) the grasslands, which cover most of the area; (2) the wooded areas along the Missouri River, now mainly flooded by Lake Sakakawea; (3) the draws on the sides of buttes and other small intermittent and ephemeral streams; (4) areas of sparse grassland on badlands along Lake Sakakawea; (5) rocky slopes of buttes; and (6) glaciated terrain.

The most widespread habitat on the Fort Berthold Indian Reservation is the grasslands, which are developed extensively north of Lake Sakakawea, especially in areas of ground moraine of the Coleharbor Group, and over large areas of the Sentinel Butte Formation. About 80 percent of the reservation is rolling grassland and badlands areas are the second most important habitat. In addition, small wooded areas occur in draws along the Little Missouri River, Lake Sakakawea and in some of the larger melt water trenches. Scattered throughout the glaciated part of the Fort Berthold Indian Reservation are numerous prairie potholes, which have a characteristic wetland type of vegetation. Finally, some of the more rugged buttes, such as the Blue Buttes at the western edge of the reservation constitute a distinct habitat.

Grasslands dominate the undulating and smoother slopes of the reservation. They are characterized by vegetation that is generally typical of the northern Great Plains. The grasslands, when near climax, support a great complexity of plants. The grass species present consist of a mixture of short grasses and midgrasses. Forbs are also well represented in this vegetative complex. Before the arrival of the white man, the abundant bison that occurred over the Great Plains found a large percentage of their forage on the grasslands.

Vegetation typical of the grasslands include blue grama, needle-and-thread grass, green needlegrass, prairie june grass, western wheatgrass, sand dropseed, threadleaf sedge, green sage, long-headed coneflower, blazing star, sandberg bluegrass, thickspike wheatgrass, little bluestem, thimble grass, yarrow, catsfoot, little sage, white prairie aster, purple coneflower, and blue wild lettuce (Johnson and Nichols, 1970).

Shrubby willows are abundant in wet places, but the most characteristic shrub is buffaloberry, which grows on the drier parts of the flood plains and in the coulees between the hills. Dogwood, juneberry (known also as service berry and Saskatoon berry), and wild roses also are common. Big sagebrush is common in a few areas where it usually grows only two or three feet high. Dwarf sage is common south of Lake Sakakawea, but it is rare north of the lake. Greasewood grows on some buttes and rabbitbrush is common. Creeping red cedar is common on the hills, especially on north slopes (Stevens, 1963).

The higher ground on the grasslands is usually rather dry and the plants that grow there are those of the prairie. However, in slightly lower places, which are moist and well shaded, species such as blue violet, fringed loosestrife, and pink dogbane can be found (Stevens, 1963).

The prairie vegetation varies greatly with relatively slight differences in elevation and soil texture, which affect the amount of moisture the soil retains. A shallow drainage way on a hillside may have different grasses and a deeper green color than the slopes only a few inches higher (Stevens, 1963). The coulees, winding among the hills, have a dense tall growth of grass and many more species of plants than occur in the sparse, short grass on the hills. According to Stevens (1963), Canada anemone, wild lily, prairie dandelion, and yellow stargrass are found in the slightly depressed areas along with a variety of grasses such as slender wheatgrass, wild rye, big bluestem, and false redtop. By contrast, the grasses of the ridges are blue grama, needle-and-thread, little bluestem, and prairie junegrass. Examples of other plants common to the ridges are the white prairie aster, fringed sage, and downy painted cup. On the driest, most exposed slopes or tops of hills, one finds white milkwort, thread-leaved sedge, gray goldenrod, tufted milkvetch, and moss phlox (Stevens, 1963).

The vegetation of the wooded draws along the Missouri River is composed of cottonwood, Missouri willow, and various other woody species native to the area (Johnson, 1971). Cottonwood, the typical tree species, is rarely found elsewhere on the reservation. Green ash, boxelder, buffaloberry, chokecherry, and wild plum also are found, but these are also common in draws and gulches along intermittent stream courses.

The third typical environment of the Fort Berthold Indian Reservation, the draws, occurs along the bottoms of intermittent and ephemeral streams, in draws and in swales. In other areas where moisture collects, shrubs and small trees dominate. The composition of this plant community may range from a simple overstory of buffaloberry with an understory of grass and forbs to a complex of woody plants in both the overstory and the understory. The coulees and draws where this environment occurs produce a great variety of species because of the favorable moisture conditions, greater snow accumulation, and some modification of the microclimate because of topography and woody plants. Some characteristic plants of the environment include green ash, box elder, buffaloberry, chokecherry, wild plum, western wild rose, wolfberry, Missouri gooseberry, western wheatgrass, red raspberry, round-leaved hawthorn, green needlegrass, wild strawberry, big bluestem, pink wood violet, wild parsley, and lambstongue ragwort (Stevens, 1963).

Badlands are extensively developed on the Sentinel Butte Formation on the Fort Berthold Reservation. Some badlands areas are completely lacking in vegetation and soil development is negligible. A sparse vegetative cover of a few grasses, shrubs, and forbs exists where some soil development has occurred. Existing vegetation is extremely important for controlling erosion which may be a determining factor in governing the plant species that occur on certain sites. For example, silverscale grows on nearly bare, saline clay soil. Suaeda also grows on the sides of eroding clay buttes. Draws between the buttes are commonly dominated by hardwoods.

A few typical plants found in the badlands environment include rabbitbrush, salt sage, silverscale, suaeda, spiny saltbrush, saltgrass, western wheatgrass, plains reed grass, Indian ricegrass, long-leaved sage, merigonum, green sage, plains muhly, blue grama, little bluestem, burning bush, tufted milkvetch, creeping cedar, and Rocky Mountain red cedar. The species of plants that occur in the badlands areas of the Fort Berthold Indian Reservation are similar to those found on sonoran desert types (Küchler, 1964).

The slopes and areas near the tops of such hilly areas as the Blue Buttes on the western edge of the Fort Berthold Indian Reservation are typified by steep, stony land. This environment occupies the highest areas because of relatively resistant layers of limestone, sandstone, or pseudoquartzite. The numerous springs, draws, depressions, scattered rocks and openings between rocks provide for a great variety of vegetation, which forms a complex including small trees, shrubs, forbs, and grasses. The variation in slope, exposure, and drainage creates a more diverse assortment of microclimates than the more level land. Most plants found in the other areas also are found in the rocky areas near and on the buttes. A few typical plants include dwarf juniper, wolfberry, ill-scented sumac, buffaloberry, plains reedgrass, needle-and-thread grass, purple coneflower, prickly pear, yucca, creeping cedar, red three-awn, and sideoats grama.

In the glaciated terrain north of Lake Sakakawea, prairie potholes are abundant. They vary greatly in size, permanence, depth, and salinity. Generally, important differences in species composition from one pothole to another can be related strongly to differences in average salinity of the water. Distinctive associations of plants may be classified as fresh, brackish, or saline, with all gradations in between (Stewart and Kantrud, 1971, 1972b). A few typical plant species include the bulrushes, cattails, liverworts, duckweed, bladderworts, various aquatic mosses, pondweed, and sedges (Stewart and Kantrud, 1972b).

Animal Life

The Fort Berthold Indian Reservation can be divided conveniently into the life zones already mentioned. The wooded areas along the river bottomlands are extremely important to animal life, particularly in the summer, since these areas have both cover and water. Species dependent on water during the dry summer months use these wooded areas extensively. Animals and birds, such as the beaver, white-tailed deer, mule deer, raccoon, red-tailed hawk, black-billed magpie, red-shafted flicker, western wood pewee, Audobon grasshopper mouse, long-tailed weasel, and plains garter snake, are typical of the wooded areas. The scarcity of perennial streams in western North Dakota makes existing streams all the more important. The surface water, especially inlets along Lake Sakakawea, and the vegetation associated with surface waters, make the river bottomlands an important habitat for many species of animals.

The draws on the sides of the buttes are important to wildlife as shelter. Some of the plants growing in these areas provide forage for deer and nesting and roosting habitat for birds. Typical animals include the white-tailed and mule deer, mountain bluebird, sparrow hawk, black-capped chickadee, least chipmunk, and striped skunk. Deer find protection in the draws from summer sun and winter storms. Sharptail grouse rest in trees and shrubs at the heads of the draws, especially in the autumn. Ring-necked pheasants use the brush as nesting cover and many species of birds nest in the shrubs and trees (Miller, 1955).

The grasslands areas, which cover most of the reservation, are the home of such animals as the mule deer, coyote, red fox, sharptail grouse, nighthawk, rock wren, brewers blackbird, northern pocket gopher, pronghorn, white-tailed jack rabbit, raccoon, black-tailed prairie dog, thirteen-lined ground squirrel, meadow vole, burrowing owl, western meadow lark, horned lark, and mourning dove. Foxes and coyotes commonly build their dens in the rougher areas along the slopes of buttes in grasslands areas. Hawks, owls, and other predators hunt the grasslands extensively (Allen, 1967). Deer use south slopes as winter range where skunkbrush and rabbitbrush are common. Sharptail grouse depend on native prairie vegetation and usually roost in upland swales and on sheltered east slopes. Many small birds nest in clumps of grass or under low shrubs. The large populations of the grasslands provide a reservoir of prey for the various predators such as badgers, coyotes, foxes, hawks, and owls. The prairies also provide nesting grounds for water-fowl wherever open water is available (Stewart and Kantrud, 1972b).

The rims of landscape, the breaks, the badlands, the buttes and the brushy draws, all constitute a variety of habitat. This variety of cover, forage, and escape areas make the badlands an important area even though vegetation is scarce. Typical birds and animals include the golden eagle, red-tailed hawk, prairie falcon, prairie rattlesnake (especially south of Lake Sakakawea although rattlesnakes are also found along the north shore of the lake), horned lizard, mule deer, white-tailed jackrabbit, desert cottontail, bobcat, red fox, coyote, horned lark, and badger. Although the climate at times is severe and the terrain is often hostile, the isolation of the badlands makes them a valuable wildlife habitat.

Devils Lake Sioux Indian Reservation

Geologic Features

The Coleharbor Group covers the entire area of the Devils Lake Sioux Indian Reservation except in a few places along the Sheyenne River valley where shale exposures of the Cretaceous Pierre Formation occur (Carlson and Freers, 1975; Bluemle, 1965). Ten different landform types, all associated with the Coleharbor Group, were recognized on the Devils Lake Sioux Indian Reservation. Descriptions of each of these geologic units follow.

The areas designated as 1 (Plate 4) are of ground moraine; these are of glacial sediment. Ground moraine on the reservation has rolling relief with a few boulders on the surface. Although much of eastern North Dakota is covered by ground moraine consisting of till, only a few small patches of ground moraine are found on the reservation. They were deposited by a moving glacier when the edge of the glacier was south of the area. This sediment consists of particles of all sizes, ranging from clay to boulders. Particles of shale are common in the glacial sediment and the shale largely is responsible for the high clay content.

Deeply eroded till slopes along the Sheyenne River are designated as 2. These areas are composed of till similar to that of the ground moraine, but boulders are more abundant on the surface as large amounts of the finer, more easily eroded sediments have been carried away. The eroded till slopes are steep and well-drained.

End moraine is designated as 3 on the map. The end moraine was deposited at the edge of the active glacier when its margin crossed the area. The areas of end moraine on the Devils Lake Sioux Indian Reservation are hilly and bouldery. They were deposited at the edge of the glacier, which was melting at about the same rate as the ice was advancing. The end moraines have locally high relief, generally between 50 and 100 feet, and numerous ridges that parallel the overall trend of the features. Some of the most rugged topography on the reservation is near Fort Totten and in the area around Sully's Hill. Sully's Hill is much higher than nearby hills and it may consist, in part, of material that was carried by the glacier from the depression in which Devils Lake is located. At least 300 feet of glacial drift was penetrated in a test hole drilled on Sully's Hill (Randich, 1971).

The area north of the North Viking end moraine, designated 4 (Plate 4), is dead-ice moraine that has rolling to rough topography. Till is the main lithology, but scattered patches of gravel and sand can be found throughout the area of dead-ice moraine.

Areas of gravel and sand deposited by water flowing from the melting glacier are shown on the map. The number 5 (Plate 4) marks areas where the water deposited the gravel on a land surface and the number 6 marks areas where gravel was deposited on stagnant glacial ice. As a result, when the stagnant ice melted, the overlying sand and gravel dropped down, leaving a rolling landscape. Where the gravel was deposited on land, the landscape is fairly flat.

The narrow, linear areas associated with the McHenry end moraine represent eskers. The eskers consist of poorly sorted gravel and sand that generally contains much shale. They were deposited by rivers of melt water flowing in tunnels and valleys in the glacial ice. When the ice melted, the gravel that had been deposited in these tunnels and valleys remained as the ridges present there today.

Flat areas that were flooded beneath the early Devils Lake (Glacial Lake Minnewaukan) when the lake was more extensive at the end of the ice age are designated as number 8 on Plate 4. Such areas of lake plain are flat and covered by deposits of layered silt and clay.

Alluvium, consisting of a mixture of silt, sand, and clay, is present on the floodplain of the Sheyenne River and its tributaries. It is designated on Plate 4 as number 9. Areas of alluvium are usually flat. They were deposited by running water in the time since the ice age ended.

An area of sand dunes is found near Hamar in the southeastern part of the Devils Lake Sioux Indian Reservation. Most of these dunes are stabilized with birch, poplar, and grass cover, but in dry years some shifting of sand takes place. The areas of dunes are shown on Plate 4 in the portions designated by the number 10.

Geologic History

Before the glaciers advanced over the Devils Lake Sioux Indian Reservation, streams drained toward the northeast (Bluemle, 1972). Early glaciations diverted this drainage southeastward cutting new channels, such as the Sheyenne River, that were used by both the diverted drainage and melt water from the glaciers.

Glaciers advanced over the reservation several times during the Pleistocene Epoch so the area is covered by several layers of glacial sediment. The materials at the surface were all deposited by the most recent glacier, mostly when that glacier was melting.

Nearly all the glacial materials exposed over the area are about the same age, between 10,000 and 13,000 years old. The relative positions of the various landforms helps give the geologist clues as to how the glacial ice behaved during this time. Areas shown as end moraine on the map are about the oldest of the glacial landforms that can be seen on the reservation. They were deposited by lobes of the glacier that moved southeastward and westward. At the time the end moraine was being deposited, melt water was depositing gravel and sand in the area southeast of Fort Totten. As the glaciers continued to melt, the direction of ice flow shifted and the ice advanced from a more northerly direction for some time. The glacier stagnated after depositing the end moraine and the materials contained in the ice slumped down, resulting in the areas of dead ice moraine (Plate 4) (Bluemle, 1974).

With continued melting of the glacial ice, the basin that contains Devils Lake filled with water, resulting in glacial Lake Minnewaukan. This lake was much larger than Devils Lake. At about the same time glacial Lake Minnewaukan was developing, large amounts of melt water from melting glaciers to the north flowed through and eroded out the valley through which the Sheyenne River flows today. While the valley was being carved, the melt water river was large, perhaps carrying as much or more water than does the modern Missouri River (Bluemle, 1974).

The hills we see today over the Devils Lake Sioux Indian Reservation may be a little more rounded due to erosion than they were 10,000 years ago, but their general configuration is essentially the same as it was at the end of the ice age. Minor changes since the ice age include the formation of dunes in the Hamar area and the deposition of alluvium in the Sheyenne River valley. Lake Minnewaukan has shrunk to the modern Devils Lake.

Vegetation

The Devils Lake Sioux Indian Reservation, like the Turtle Mountains, has a woodland flora similar to that of western Minnesota or southern Manitoba. Although wooded areas on the reservation are similar in many ways to those in the Turtle Mountains, local factors such as changes in elevation, slope direction and other factors seem to exert a somewhat greater influence on the flora and cause it to vary more over shorter distances. The largest forested area is on and around Sully's Hill.

Generally, north-facing slopes in the Fort Totten area are covered with bur oak. Near Devils Lake, a mixture of paper birch, green ash, box elder, and basswood occurs. Aspen is common in places, particularly in areas of sand dunes. American elm is present on bottomlands. Highbush cranberry occurs along Devils Lake in places whereas arrowwood is common wherever the overstory is sufficiently open. Several types of willows occur in certain melt water trenches, such as Seven-mile Coulee where the water table is high. Beaked hazel is common in wooded areas around Free Peoples Lake. Other shrubs common in wooded areas include currant, gooseberry, and snowberry. Chokecherry, hawthorn, and juneberry occur along the edges of wooded areas near Sully's Hill.

The Devils Lake Indian Reservation has numerous ponds and sloughs, most of which formed when blocks of buried, stagnant glacial ice melted at the end of the ice age. Many of the ponds are permanent and contain relatively fresh water, but most of them tend to be brackish. A few typical plant species include the bulrushes, cattails, liverworts, duckweed, bladderworts, various aquatic mosses, pondweed, and sedges (Stewart and Kantrud, 1972b).

Unfarmed areas of prairie on the Devils Lake Sioux Indian Reservation are, in many places, invaded by wolfberry. The native grasses and associated forbs are most abundant in areas adjacent to woodland and on isolated prairie within the wooded areas. The rolling, open prairie lands may be covered by Kentucky bluegrass, prairie drop-seed, skeleton weed, white-stemmed evening primrose, and white larkspur.

Animal Life

Most of the animals now found on the Devils Lake Sioux Indian Reservation have been there since prehistoric times, with the exception of the raccoon, which was not present in the area until about 1900. Until late in the 19th century, bison, elk, moose, and bear were common in the area. Today, both bison and elk are maintained on the Sully's Hill Game Preserve. Mule deer and whitetail deer are common. Coyotes are common on the reservation. Other mammals include the porcupine, red squirrel, least chipmunk, snowshoe hare, and silver-haired bat (Collins, 1959).

CHAPTER V

SUMMARY

The purpose of this dissertation is to provide a sample course outline and resource materials to be used in teaching a natural science course of the Great Plains, stressing especially the natural science of North Dakota's four Indian Reservations. Natural science, which is best studied in the field, includes field geology, climatology and meteorology, soils, astronomy, and field biology. A realistic appreciation of natural science is gained only when all these disciplines are treated as an integrated unit. I believe too that an overall natural science perspective is particularly important to students not majoring in science.

This dissertation was intended originally for American Indian college students to fill the need for a natural science field course and to provide a transition between traditional plains Indian cultures and conventional natural science as it is treated at the university. I first realized the need for specific courses in natural science for American Indian students when I was a science-math tutor of American Indian students at the University of North Dakota in 1971-72. Courses in humanities, social sciences, and education have already been developed within the area of Indian Studies at various colleges and universities, including the University of North Dakota, but Indian Studies courses are needed in the sciences as well.

For a number of reasons, Indian students have often found the social environment and the value orientation of colleges and universities alien and for this reason they have found it difficult to adjust to college life. I became convinced that a field course dealing with the natural science of North Dakota and its Indian Reservations, would be an effective method for introductory North Dakota Indian students to science. Because of this conviction I decided to become a more knowledgeable natural science educator, and to design an Indian Studies sourcebook and sample course outline in the natural science of the northern Great Plains especially tailored to the four North Dakota Indian reservations and to the American Indian students entering our colleges.

My interest in developing a natural science course was stimulated by opportunities to make extensive field observations throughout North Dakota during the summers of 1968-1972, to teach a number of science courses at the University of North Dakota to Indian students on their own reservations as well as on the university campus, and to study the geology and biology of the reservations. During the summer of 1975, I taught Natural Science of the Great Plains, Arts and Science 250, to Future Indian Teachers at Fort Yates and White Shield, North Dakota. That course was based principally on the material in the sourcebook, Chapters III and IV, of this dissertation and the reference materials in the appendices. I consider the lesson plans and the roadlogs, Appendices C and D, a valuable part of the resource material, but they were not included in the body of the dissertation because I did not want to break the continuity of the natural science discussion.

The teaching, field work, research, and study, which have culminated in this dissertation, have increased my insight into the art of teaching as well as my knowledge of the peoples and physical environment of the Great Plains. It has strengthened my conviction that subject mastery and careful planning of lessons are the initial steps in a successful relationship with students. It is clear to me too that a teacher must adapt himself/herself and the course content to the individual personalities and background of the students.

Few integrated science curricula materials that relate to the natural science of North Dakota are available and, of those that do exist, almost none are related to the North Dakota Indian reservations. Each of North Dakota's four reservations has a community college and this dissertation should be particularly useful in the introductory science programs, especially as these colleges introduce field courses related to areas close to their campuses.

This dissertation has such a broad coverage that it should be regarded as a reconnaissance work, outline, and overview of the broad aspects of the natural science of the Great Plains. My experiences have convinced me of the need for educators and scientists to prepare much additional specific curricula for field courses in the northern plains. These courses might, for example, center around mammalogy, for the traditional Indian respect for the animals and their use was reflected in their customs, in their religion, and always in their day-to-day living. Botanists might develop field courses built on the theme of the dependency of Indian culture on plants for medicine and food. There is a need not only for recognition, but for an in-depth study of certain plants of the northern plains, which long offered nutritive and/or medicinal effects to the American Indians. Anthropologists and archaeologists have been able to piece together the life styles of peoples living along the Missouri River (Lehmer, 1971; Wood, 1969) but little is known about the life styles of prehistoric people who lived away from the rivers in the northern plains (Chris Dill, North Dakota State Museum of History, personal communication, July, 1975).

All of North Dakota's schools, regardless of their location, need science field activities developed for their own localities. This dissertation should point some possible directions for the development of such science field activities. I suggested that experienced classroom science teachers who reenter graduate school to learn more about the art of teaching and also to strengthen their knowledge of a particular science might concentrate on the natural environment adjacent to the school in which they teach. They could develop a sourcebook, references, and many lessons related to their own school area.

Many schools are close to parks, wildlife refuges and game management areas. I hope that educator-scientists will write field guides and nature walks, and introduce discussions pertinent to such interesting areas. For example, a nature study of a pond might include a boardwalk leading through willows and cattails to the center of the pond thereby making parts of the pond that were previously accessible only by waders or canoe, available for study by students of all ages. This has been done at Riding Mountain National Park (see Appendix C, sample lesson 13), and I would like to see it done, where conditions permit, in various parts of North Dakota.

I accomplished my original intent to produce a syllabus and a sourcebook consisting of material dealing with the natural science of the northern plains and the North Dakota Indian reservations and pertinent appendices, especially Appendices C and D, which are field studies made up of sample lessons and roadlogs of the reservations. These have helped me in my own teaching and they should help others who are working on integrated natural science courses in North Dakota, especially in relation to the Indian communities.

APPENDIX A

Keys, Study Aids, and Pertinent Natural Science Literature of Probable Use to Teachers and Students

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Useful Periodicals

The reader is referred to A guide to magazines, newspapers, and periodical indexes (Scott, 1973) for full descriptive and bibliographic information about the following periodicals. Subscription prices are not included here as they are subject to frequent change.

Audubon is the official publication of the National Audubon Society. It reports conservation news and natural history items from a world front. Of particular interest are the magnificant photographs in black and white, with some in color. For all levels.

BioScience, a publication of the American Institute of Biological Sciences, reports the findings of research in the biological sciences with emphasis on those aspects that affect man's quality of life. The magazine is scholarly, but interesting and readable. Advertising is useful to teachers.

Dakota Farmer, as suggested by the title, is dedicated to the interests of farmers and their families. The advertisements and illustrations open up a foreign world to the urban child. Articles deal with everyday aspects of science important to rural Dakotans.

Living Wilderness, publication of the Wilderness Society, is particularly concerned with educating citizens to participate politically in conservation matters. It is useful with high school ecology activities and interests.

Natural History is generously illustrated and therefore of interest to the elementary student even though the articles are written in a scholarly fashion. The full range of the natural sciences is covered--from monthly star charts to anthropology. It is published by the American Museum of Natural History.

Rock and Gem treats mineralogy in a popular manner. Places where gems and precious stones can be found are listed, and lore surrounding gems is included. The illustrations are both interesting and excellent.

Science News is an excellent summary of recent science events in the news. It is highly readable and the information is useful to junior high, high school, and college students. The full range of natural sciences and physical sciences is covered.

Scientific American gives a broad coverage of the field of science. The articles are scholarly, but readable and of interest to the advanced high school student. Excellent illustrations and charts as well as an attractive format make the magazine appealing.

Sky and Telescope is concerned with developments and observations in the field of astronomy. The sky chart includes detailed explanations of month-to-month changes in the sky.

Weather, a publication of the Royal Meteorological Society, is technical in content, but includes unusual black and white photographs of weather phenomena. A few features of particular interest to young people--weather maps, etc.--are included in each issue. General science and earth science programs could make use of this publication.

APPENDIX B

RELEVANT EDUCATIONAL FILMS

I judged the films listed below to be of value in developing courses related to this syllabus. I have pre-viewed a great many audio-visual aids now on the market, which are related to Indian cultures and to the general science of the Northern Plains. Very few were worthy of classtime. However new audio-visual aids on these subjects appear each month and, in planning a course, an instructor should investigate what is currently available.

The films are listed and described in the NDSU FILM Catalog of 16 mm Films, 1975-1977, on the pages noted. The catalog is available at most North Dakota schools. You may obtain further information from Lillian M. Wadnizak, Library Manager at the:

North Dakota State Film Library
State University Station
Division of Independent Study
Fargo, ND 58103
Area Code 701 237-8907

p. 121-122	Looking at Fishes Looking at Amphibians Looking at Reptiles Looking at Birds Looking at Mammals
p. 180	Sioux Legends
p. 193	Tahtonka: Plains Indians Buffalo Culture
p. 206	Vanishing Prairie (Parts 1,2,3,4)
newly purchased	Glaciation of the Interior of North America (not listed because purchased after catalog went to print.)

APPENDIX C - LESSON PLANS

LESSONS FOR STANDING ROCK INDIAN RESERVATION

Sample Lesson 1: Comparison and Contrast of Two Habitats

I. Aim: To contrast the widely differing habitats found at the Porcupine Creek badlands with the habitats found at the Froelich Dam Wildlife Management Area by searching for a variety of plants and animals, or their sign, and noting the environment in which each is found.

II. Approach: What animals do you expect in the badland area? Where is the prairie rattler most likely to be found in the daytime? Do you know of any extinct animals that may have inhabited this area in historic or prehistoric times?

III. Procedure

A. Porcupine Creek Study Area:

1. Allow students a half hour for individual exploration: specimens may be collected, photos taken and temperature readings made in four distinctly different habitats of the area

2. Field trip of area guided by instructor

   a. On geologic maps and county road maps study what can be learned about this small area
   b. Discuss phenomena observed here and organize observations into sub-headings: geology, soils, microclimates, plants, animals.
   c. Walking over the area and using a variety of references discuss its geology and poor soil development. Search for fragments of dinosaur fossils, lichens of about four kinds, and more highly developed plants. Note the ways some have grown in response to the prevailing winds. Also note animal sign and vertebrates, including hawks or golden eagles.

3. Review of the day's lesson thus far: on geologic map contrast the Porcupine Creek Study Area with the Froelich Dam Game Management Area twelve miles south and note the change in geology. While driving to the Froelich Area note the change in overall environment and types of habitat provided for plant and animal life.

B. Froelich Dam Wildlife Management Area

1. This is native grassland, occasionally interspersed with windbreaks in different stages of maturity. The lake

behind the dam has a variety of water-fowl and shore birds abound. The sand beach is made up, in large part, of iron-stone concretions weathered out of the Hell Creek Formation. It is a fertile area and the grass provides a home for many prairie birds and animals ranging from fox, badgers, and mule deer, to meadow mice and thirteen-lined ground squirrels. Animals that thrive on the edge of a forest live in the windbreaks. The combination of rolling prairie grassland and planted windbreaks, excellent water supply, and wise game management practice makes this area one of the best places on Standing Rock Reservation to study the natural science of the northern plains within a small area.

2. Field trip of area guided by instructor: follow the same procedure as in the Porcupine Creek Study area, contrasting this area with the one in which the class spent the morning.

3. Review the day's activities thus far. Lead students to draw conclusions about the different types of landscape and soil development seen, the response of plants to prevailing winds, temperature and available water, and the type of habitat typical of vertebrates seen during the day.

IV. Assignment: Record the most vivid impressions of the day, comparing and contrasting the two study areas and also briefly write such a comparison and contrast for the instructor in evaluating the day's study.

V. Materials and Preparations Needed

A. Instructor should have studied both areas before bringing students to these areas.

B. Students should have their own copies or access to field guides and references of many types, geologic county and other types of maps, as well as binoculars, compasses, and thermometers.

Sample Lesson 2: Visit to Sitting Bull's home site in the Grand River valley

I. Aim

A. To increase the knowledge of and respect for the cultural heritage of the American Indians.
B. To increase knowledge of the work of rivers and the soils, plants and animals of a region that has been subjected to the geological work of a river such as the Grand River near Bullhead, South Dakota.

II. Approach: Briefly outline the historical events that happened there within the past century

III. Procedure

A. Drive to the site

1. Note the site of the last great buffalo harvest (1883).
2. Contrast the topography, soil development and domesticated plants on the alluvium near Fort Yates, the Cannonball Formation and Hell Creek Formation, both of which are crossed, or seen on the horizon as one drives south to the Sioux-Corson County border. Note the Pierre Shale outcrops in Corson County, the topography developed upon it, and the types of crops that seem to do well in this area.

B. Descent to the banks of the Grand River: it is wise to have a driver-guide who knows this area well, such as one of the teachers or the bus driver from the Bullhead, SD, public school.

1. Note the clay road that is followed for two miles: this is bentonitic clay (known locally as "grease.") On rainy days it is impassable because it does act just like grease.
2. After leaving section line road and beginning the descent to the river stop the vehicles several times, allow the class to explore the native prairie and the bush-filled ravines.

    a. Collecting is permitted: students might be divided into groups to collect a variety of plants. These could be pressed immediately or remain in plastic bags and placed in leaf press upon return to the classroom.
    b. Watch for the pair of bald eagles that lives in this territory and fish the Grand River.
    c. Note the log cabins and the grave markers, built on the first terrace above the Grand River. The smaller cabin, built in the 1920's, is erroneously pictured as that of Sitting Bull in the State Historical Building in Bismarck. Actually his cabin was burned the morning he was murdered. The grave marker is at the approximate site of his cabin.

    The graves are those of some who were killed in the fight when Sitting Bull was killed and a commemorative plaque in Lakota and English records the happenings.

This land is owned by an elderly lady in Bullhead, SD, who was a girl of seven years when the Ghost Dance took place. She was present when Bullhead and his police arrived from Fort Yates to capture Sitting Bull on the morning of December 15, 1890.

d. Effects of rivers.

   1) Observe the banks of the Grand River: what evidences of erosive forces are here? Can you find any blocks that have rotated in their downward descent?
   2) How is the land being eroded away and the river cutting back into the terrace? What could cause this?

e. Visible animal or animal signs

   1) Prairie dog town

      (a) Watch the prairie dogs with binoculars
      (b) Observe dogs/rodents and their actions when town is approached

   2) Search wooded draws for animal and/or animal sign
   3) Watch for pair of bald eagles and their nest in a tree overhanging the Grand River; observe flight of eagles through binoculars

f. On return to section line road note the natural road, made of bedrock, turn from bentonite to sand, to other materials as the car ascends from the valley

C. Student-instructor summary: a discussion period, either walk-over the area, or in the field vehicles on the return

IV. Assignment: Personal entries in student diaries

V. Materials needed: field guides of many types, county road maps of Sioux and Corson counties, state highway maps of North and South Dakota, geologic map of Sioux county, and one of Corson County if such is available at the time.

Sample Lesson 3: Prolific fossil site, and surrounding area, which includes deer beds, swallow nests, and the habitat of a great variety of animals of the northern plains

I. Aim

   A. To introduce students to marine fossils found in-place.
   B. To lead students to observe the great number of living grasslands creatures and signs of their presence in a tree-lined gully bordered on either side by native grassland

II. Approach

A. Refer to previous study of fossils

B. Mention current life that abounds in the area: the swallows that nest in a nearby culvert; a doe and twin fawns that have been seen here; raccoon tracks usually found in the soft sand close to the water level.

III. Procedure

A. Leaving cars at field approach, walk over the grazed, native grassland and descend slope to draw

1. Note change in height of mature grasses: the taller and "lusher" meadow is closer to the water table

2. Watch for signs of ripening grass; for flowering grasses. How many colors of flowers do you see? Can you identify some of them?

3. Walk down the floor of draw and note that it becomes damper as the water table is approached.

   a. Examine the outcropping Fox Hills Formation on sides of draw.
   b. Watch for signs of living and once-living creatures.
   c. The Fox Hills Formation outcrops in all of the gullies in this area and the fossil, Tancredia americana, as well as a variety of other fossils are found in the iron-stained member.
      (1) Examine the fossils "in-place" and find specimens that have weathered out into the gully bed
      (2) Collect and identify (if possible) those specimens for which you will have later use for a personal collection, or for a classroom. On collecting bag note date and location. (Instructor should discourage wasteful collection.)

B. Over a coffee break on the side of the gully spend some time just "looking" at the environment. What do you see? What do you hear? Allow students about a half hour to wander, enjoying and learning about the area. (Though this area adjoins a major road, just seven miles from Fort Yates, no students had ever spent time here. I have taught this lesson, in various ways, to several different classes.)

C. Instruction.

1. Using fossil guides, what can you learn about your collections?
2. Instructor should point out deer beds, animal tracks, and perhaps some birds or other animals will be seen.

IV. Assignment

A. Entries in personal diaries of most outstanding part of day's study.

B. Brief evaluation of the field trip, which also outlines what most impressed each student.

V. Materials needed: county and geologic road map of Sioux County, variety of field guides.

LESSONS FOR FORT BERTHOLD INDIAN RESERVATION

Fort Berthold--Little Missouri Bay State Park

Introduction

Little Missouri Bay State Park, near Mandaree, North Dakota, is adjacent to the Fort Berthold Indian Reservation. The park includes badland areas and natural habitats similar to those found in relatively inaccessible parts of the Fort Berthold Indian Reservation. Lessons 4 through 7 are intended to be used in Little Missouri Bay State Park. However, they could be individually adopted, serving as sample field lessons for field study on other parts of the Fort Berthold Reservation.

This series of lessons begins with a field trip from a central gathering point at Newtown, North Dakota, and follows the Newton-Mandaree roadlog (Appendix D) as far as the Mandaree corner. The class would then continue south on Route 22 to the Little Missouri Bay State Park entrance and turn left (east) into the park.

I have planned this series of lessons in such a way that the students would camp in the park for two nights and three days. This is a primitive park with two log shelters, including electric outlets and five artesian wells at the entrance way. Spruce Hill Ranch provides trail horses, as well as pasturage for personal steeds visitors may bring to the park.

Though spectacular areas are found in Little Missouri Bay Park, the park shares its most outstanding feature with the rest of the northern Great Plains: the balance of nature evident in the adaptation of the animals and plants to the habitats for which they are fitted, and the development of soils.

Sample Lesson 4: Orientation

I. Aim

A. To introduce students to the park
B. To show the use of topographic maps and air photos for orientation

II: Approach: Orient students to park by means of topographic maps, aerial photos and map of park

III: Procedure

A. Allow time for students to explore immediate surroundings and choose camp sites
B. At specified time meet to set up camp: new campers should be guided in their search for a comfortable tent site
C. Before sundown allow time for exploration of the wider foot paths surrounding camp which lead from arid cliff-faces, to grasslands, over streams and into a thick, broad-leafed forest in a sheltered cliff-face that is fed by artesian springs

IV. Assignment: To orient self, by use of sun, compass, and topographic sheet

V. Materials needed: compasses, topographic sheet, field guides, binoculars, camping equipment including food

Sample Lesson 5: Walking Transect of a Canyon

I. Aim: To gain some concept of the diversity of habitats in Little Missouri Bay Park

II. Approach

A. Note the diversity of relief, watersheds, and other pertinent information on topographic maps
B. How will the soil, rock exposure, plant growth, animal habitat and mini-climates reflect this diversity of relief?

III. Procedure: Follow worn paths about a quarter of a mile to the top of the nearest badland outcrop

A. Sight a Rocky Mountain Juniper, or other landmark, on the highest tableland to be seen across the ravine
B. Transect the valley, recording mentally and by camera if desired, the changes in bedrock, soil, plant life, and animal sign
C. Ask yourself many questions as you make the transect: try to "tune in" on the canyon

1. What is the composition of exposed bedrock?
2. Are you being watched? Bald eagles claim this as part of their territory as does a pair of rough-legged hawks
3. What temperature changes does your body record? Humidity changes?

IV. Assignment

A. Physically transect the ravine in approximately three to four hours: as a safety precaution students should travel in pairs
B. Write a "Journal of the Canyon Transect" after returning to camp recording those observations that most impressed themselves on all of your senses

V. Materials needed

A. Water in canteens attached to body
B. Field guides, notebooks, and binoculars only if they can be firmly attached to the body; sharp pocketknife, liquid Cutter's lotion, concentrated trail food
C. Durable, weather-conscious clothing, especially dependable heavily-soled walking shoes, boots, or tennis shoes with some form of welted sole

Sample Lesson 6: Different Compositions of Bedrock

I. Aim: To see the different textures and minerals in the different beds of the Sentinel Butte Formation

II. Approach: Observe a lignite or leonardite outcrop that is well-vegetated in contrast to the barren clay or sand members above or below the member. What reasons might cause this?

III. Procedure

A. Have students observe, and climb over various beds listing differences in vegetation, color, texture and compsotion of bedrock, and the angle of erosion of the various members
B. Walk several outcrops, contrasting areas that have more severe wind and sun exposure with areas that are more protected from the severe winters or from high winds
C. Discuss what is seen, introducing (or repeating) the terms bentonite, lignite, leonardite, gypsum and gypsum crystals, fine sand, sand concretions and other geological phenomena well-exposed there

IV. Assignment: Sketch one of the best exposed outcrops, and describe the lithology of the various beds

V. Materials needed: Maps, North Dakota stratigraphic column, notebooks, meter sticks and other calibrating tools if available, personal water canteens and other equipment

Sample Lesson 7: Habitats of Little Missouri Bay Park

I. Aim: To give the students an intimate knowledge of the variety of terrain, and resulting habitat in Little Missouri Bay Park

II. Approach: Refer to the rigorous transect of valley by foot which covered less than a mile. Most of the park can be seen only on horseback because of the terrain.

III. Procedure

The guides from Spruce Hill Ranch are excellent in helping students to choose suitable mounts. The horses used for trail riding are docile, sure-footed animals. Novice riders should be shown how to keep tight rein and the proper way to sit tall in the saddle. After a half mile on the trail, which is initially over a flat meadow, the novice riders will gain sufficient horsemanship to observe and enjoy the remainder of the trip.

Students should try to record by eye and memory what they see: notetaking is best done back in camp. It is important that they observe constantly, ask innumerable questions of the guide, each other, and the instructor. Body reactions to changes in altitude, sun-exposure, meadows or creek beds and the rhythm between rider and horse should all be part of the student's awareness.

In many ways, this lesson provides a review of the course thus far. The students, without use of field guidebooks, will find that they recognize many of the grasses and forbs; the birds and animal sign as well as the animals that thrive in the park. They will recognize, by color, grain size and texture, the difference between members of the Sentinel Butte Formation exposed on badland slopes.

Allow an hour to an hour-and-a-half of rest at noon. Take a half hour of that time to summarize the areas thus far covered in notebooks, the natural phenomena that have been observed, and questions students may have.

IV. Assignment: After returning to camp, sometime before sundown, record the most vivid impressions of the day in personal field diaries.

V. Materials and preparations needed: Horses adapted to skill and size of riders, water canteens, necessary sun protection, food, first aid remedies, sensible clothing including leather-soled shoes or riding boots, various maps of the region, and field guides.

After the students have been thoroughly introduced to the park and taken part in some of the formal lessons, some time should be set aside for them to pursue private study and to return to points special interest to individual students.

Lesson Involving a River Woodland Habitat

Sample Lesson 8: The Missouri River Valley Between the Garrison Dam and Washburn, North Dakota

I. Aim:

  A. Knowledge of the pre-Lake Sakakawea appearance of the Missouri River Valley
  B. Introduction to sand bars, river beaches, floodplain and terraces and the typical vegetation of each
  C. Further knowledge of North Dakota vertebrates

II. Approach: Reference to Elbowwoods and the flooding of the Missouri River valley, including the homes of many of the students

III. Procedure

  A. Discussion of the good and bad effects of Garrison Dam
  B. Brief tour of the Riverdale aquarium which shows game fish found in Lake Sakakawea
  C. Approach the river via the road leading to, and past, the campsite behind the fish hatchery
  D. Teacher should allow time for some exploration and then point out the geological features to be seen and the fluvial processes at work; note the different soils and the plants that have developed close to the water. Note the very large trees: bur oak, boxelder, cottonwood and green ash grow much larger in the river bottoms than in most of the hardwood draws found interspersed with grassland away from the river.
  E. Watch for animal tracks along the river, for many four-legged vertebrates live in this river habitat. With the binoculars attempt to identify some of the great variety of birds that are found in the Missouri valley.
  F. Stop at stripped area when returning to main highway. This is a flat terrace, now a wasteland, above the river that was stripped twenty-five years ago. No topsoil was replaced at that time and none has developed since then.

IV. Assignment: Collect, press and identify five herbaceous plants, and the leaves and twigs of five trees found in the Missouri River valley. Write a brief paragraph which summarizes and evaluates the trip.

V. Materials needed: Compasses, plastic collecting bags, binoculars, plant press, animal and plant keys and references

LESSONS FOR TURTLE MOUNTAIN AND DEVILS LAKE RESERVATIONS

Riding Mountain National Park

Introduction

Riding Mountain National Park in Manitoba, Canada, is as diverse as is Little Missouri Bay Park in North Dakota and no two natural areas in the northern plains could be so different from one another. Riding Mountain has the subtle topography typical of a glaciated landscape found also in eastern North Dakota and the altitude in parts of the park allows for sufficient rainfall to develop densely forested terrain. Little Missouri Bay Park, which is mostly within the breaks of the Little Missouri River and encroaches on Lake Sakakawea, is a semi-arid region with a landscape sculptured by wind and flash floods, rather than deposited by glacial action.

During the past ten years Riding Mountain National Park has been intensively studied by the naturalists who work there. This study has included the geology, soils, plants and animals, and climate of the park. At the Interpretive Centre an overall perspective of the park is given by means of dioramas and slide lectures. It introduces the three biological communities, and typical animals of each, that occur in the park. In the areas of the park open to the public are at least fifteen well-developed hiking trails, varying in length from short, self-guided nature trails to trails more than forty miles long.

The park is a nature reserve encompassing 1,150 square miles. It is the only place in this part of North America where eastern hardwood forest, northern pine-aspen forest and the native grasslands meet. Much of it is a large mesa, covered by glacial deposits similar in geologic origin to those at Duck Mountain Provincial Park, and with a topography resembling that of the Turtle Mountain Indian Reservation in North Dakota.

Riding Mountain is 120 miles north of the International Peace Garden, adjacent to the town of Wasagaming, Manitoba. Maps and other materials on this area are available by writing to: The Superintendent, Riding Mountain National Park, Wasagaming, Manitoba ROJ 2HO.

I believe that in planning a field trip to this area, the teacher would benefit by spending several days camping there and going over the area and many of the nature trails with some of the naturalists and planning the class trip on site. If this is not possible, by all means contact the superintendent directly and have him direct you to a capable person who can plan a worthwhile field trip with you.

Lessons 9 through 13 deal with a field trip to Riding Mountain National Park although parts of them could be individually adapted to similar areas in the Turtle Mountains in North Dakota or Fort Totten. Lesson 14 deals with a marsh in prairie pothole country and it is intended to be a one-day field trip for the Turtle Mountains, Fort Totten, or, possibly, the Fort Berthold Reservation.

Sample Lesson 9: Reconnaissance of the International Peace Gardens

I. Aim

   A. Orientation of students in park where they will camp
   B. Introduction to natural science of the area

II. Approach: Road logs of the Peace Gardens

III. Procedure

   A. Drive the road log, making suggested stops
   B. Locate camping grounds arranged for ahead of time

IV. Assignment: Personal journals

V. Materials needed: Road logs of park, plant and animal keys, camping gear and food

Sample Lesson 10: The Peace Gardens Birch Trail at Dawn

I. Aim: To become acquainted with the plants and animals of a birch forest and the activities taking place in a forest shortly after dawn

II. Approach: Verbally contrast the type of climate and general environment that would encourage birch, rather than prairie grass to grow here

III. Procedure

A. Walk quietly, trying to see small and large animals, as well as their sign
B. Observe some of the most common plants growing in the understory and identify the different trees found here
C. Compare the trunks of birch trees with those of aspen and balsam poplar; compare the bark; compare the leaves
D. At lake at end of trail a beaver family lives, loon breed, and a large variety of water birds and animals live here. Shore birds and woodland animals and thick underbrush is a definite contrast to the prairie plants and animals more often observed in the Northern Plains
E. Retrace steps to main road

IV. Assignment: Notations in personal notebooks

V. Materials needed: Weather-conscious clothing, binoculars, plant and animal field guides

Sample Lesson 11: Drive from Peace Gardents to Riding Mountain National Park

I. Aim: To gain a reconnaissance view of the effect of both altitude and latitude upon the northern plains

II. Approach: After passing Customs, driving northward, note the same terrain and general plant assemblages as on the North Dakota side of the Turtle Mountains. How is the descent off the Turtle Mountains reflected in the plants? How is the lowland area similar and different from that around Dunseith or south of Belcourt?

III. Procedure

A. Watch for, and carefully record the abrupt change in plant assemblages with altitude as the Turtle Mountains are descended.

B. Note the glaciated terrain in the Turtle Mountains; some large melt water channels, some prairie potholes. What cultivated crops seem to thrive here?

C. Note the beginning of the birch aspen parkland, and finally note the first native pine and spruce stands.

    1. What explains the aspen-poplar parkland in the Turtle Mountains?
    2. What changes explain the aspen-poplar parkland and finally a spruce forest in the drive 120 miles north?

IV. Assignment: Personal diary

A. Entries in personal journals
B. Knowledge of Canadian and United States customs regulations
C. Introduction to Riding Mountain on pp. 105-106 of "Manitoba, Canadian Vacation Handbook."

V. Materials needed

A. Maps and roadlogs of the areas covered
B. Personal identification, such as driver's license, for customs identification
C. Plant and animal keys

Sample Lesson 12: Introduction to the Riding Mountain Park at the Interpretive Centre

I. Aim: To introduce students to the natural science of Riding Mountain National Park, Manitoba.

II. Approach: Because of the difference in altitude within the park, three biological communities are found:

A. Eastern hardwood forest
B. Northern pine-aspen forest
C. Grasslands

Animals typical of each community live in these areas and those to be found in each community are preserved, with their habitat, in dioramas at the Interpretive Centre.

III. Procedure

A. Allow sufficient time for students to study dioramas, and take in the general setting of the Interpretive Centre
B. Slide lecture presentation by naturalist followed by question and answer period

IV. Assignment: Use your powers of observation and your ability to remember rather than taking notes at the Centre. You will want to make later entries in personal journals.

V. Materials needed: Maps of the park, itinerary for the day

Sample Lesson 13: The Life of the Pond: Ominnik Marsh Trail (1.2 miles)

I. Aim: To intimately view a typical willow marsh and cattail swamp by means of a boardwalk that takes students to the very center of the swamp after passing through the marsh.

II. Approach: The naturalist is the ideal person to give an introduction to this lesson as the class walks from the Interpretive Centre over the boardwalk. The entire marsh and swamp community is almost identical to that found in the Turtle Mountains and very similar to that found in other parts of glaciated North Dakota, especially in areas of stagnant ice topography. To me it is the most relevant and one of the most interesting of the lessons at Riding Mountain because all of the students I have taken on this walk are acquainted with swamps, but never have deliberately examined the center of one in the summer-time. Here, they can do so in the comfort and safety of the boardwalk.

III. Procedure: Naturalists of the area will divide the group into about five students apiece and go at a pace that allows for many student questions, while they can talk about the plants, the animals and animal sign, and the marsh itself. No matter how many times the teacher may have taken the same walk, the naturalists will have much to contribute, because of their daily knowledge of the area. It is wise to let them do the instructing.

IV. Assignment: Observe and record observations in diaries

V. Materials needed: Only the park map, for purposes of orientation

Further lessons on Riding Mountain: There are six camping sites within the park, and so much to be learned in the region that one night spent there would give much more time to explore this vast and naturally interesting place. Lessons could be built around the burls-bittersweet area in the eastern hardwood section of the park, around the buffalo prairie, or the fifteen different nature trails. By corresponding with the naturalist in charge of the park the individual instructor of a class can plan the best itinerary to include lessons valuable to his class and within the allotted time for this part of the course.

Itineraries are necessary on extended field trips, and no two itineraries are ever the same. I have included a sample used when a class of biology undergraduates, Future Indian Teachers, spent one day at Riding Mountain National Park. Copies were distributed to them several days before the trip and also to the bus driver. In this class most were married and wanted their children and husbands or wives to share part of their experience. The bus driver had time to plan our transportation.

Itinerary for Field Trip to Riding Mountain National Park

6:30 a.m.	Leave Belcourt H. S. parking lot. Travel to Riding Mountain National Park via Dunseith, Peace Garden, Canadian Highway 10 through Boissevain, Brandon, Wasagaming.
6:45 a.m.	Pick up Dunseith students at Dale's Truck Stop.
9:30 a.m.	Arrive at Wasagaming information bureau. Briefly pick up pamphlets and other material that may interest you. Reboard bus for Interpretive Centre. Here is the naturalists' headquarters and exhibits.
10:00 a.m.	Naturalist will meet our group. He will give introductory slide exhibits in this building.
11:00 a.m.	Directed nature walk over boardwalk into willow swamp and cattail marsh.
12:00 m.	Lunch. Picnic in eating area behind, or to one side of building.
12:30 p.m.	Board bus for eastern drive. This will take us up onto the Manitoba escarpment into the most forested area of the park. Here are found animals typical of the northern coniferous forest such as beaver, marten, elk (wapiti), moose, bear, wolves, etc.
3:00 p.m.	Take self-guiding trail that terminates the eastern drive. This is a walking nature trail with explanatory pamphlets provided at its beginning.
4:30 p.m.	Time to explore different areas around Wasagaming.
5:00 p.m.	Board bus for Belcourt at Interpretive Centre.
9:30 p.m.	Arrive in Belcourt, returning by same route.

1. Wear comfortable hiking clothes.

2. Provide your own lunch and supper. There will be coffee and rolls on bus in the morning. If you wish, we can have a large cooler and ice to keep supper food cold. (Anybody have a freeze-block for the cooler?)

3. Several have asked about meeting their families after the field trip. Either the information bureau or Interpretive Centre are easy to locate. The "Vacation Handbook," pages 99, 106, 110, 117, and 125 might be of special interest to you and your families.

Prairie Pothole Country

Sample Lesson 14: A Marsh

I. Aim: To introduce students to the geology, plants and vertebrates of a Turtle Mountain marsh.

II. Approach: Refer to the lakes, marshes, and damp hayfields noted in fieldtrip which follow the road log of the Turtle Mountains. Review the concept of lake succession.

III. Procedure

- A. On a warm day proceed to a marsh with little standing water
- B. Reconnaissance of pond
    1. Walk around the shoreline attempting to identify as many trees, shrubs, sedges as possible
    2. Make a transect from the outer circumference to the center of pond. Sketch the descending height of the plants. Gather specimens of what seem to be dominant species at each level of descent, press these and attempt identification of the most common species.
- C. Note the way in which the senses react to the marsh. How does it smell? How does it feel to your bare feet, and to your fingers? What various colors are the blooming flowers? Listen to the frogs and other animals. What birds do you see?
- D. Allow the students some time to explore the marsh and record observations of phenomena.

IV. Assignment: Written discussion of predominant plants encountered in transect of pond and sketch of transect made from outer circumference of pond to its center.

Sample Lesson 15: Sully's Hill. The diverse habitat and the larger vertebrates at Sully's Hill Game Management Area near Devils Lake, North Dakota

I. Aim

- A. Insight into the effect of minor changes in altitude, direction of exposure to sun and wind and available water on vegetation
- B. Some understanding of the interrelation between larger vertebrates and their environment

II. Approach: What are the kinds of vegetation found at Sully's Hill Game Preserve? Speculate on reasons for such diversity

III. Procedure

A. Drive through the game preserve recording the altimeter reading every quarter mile

1. Note typical vegetation at each stop
2. Note animals or animal sign at each stop

B. Life of the pond

1. What vertebrates are very much in evidence?
2. Can you locate other vertebrate tracks along shoreline?
3. What is the dominant vegetation?

C. Life of prairie and forest

1. Explain implications of "edge effect." Note the large amount of grassland bordered by easily accessible shrub and tree cover which should provide a habitat for a great variety of species
2. Locate buffalo herd: observe same
3. Watch for the elk and for the deer. (I have seen both of these species more often at twilight and at dawn.)

IV. Assignment: Written summary of initial field trip and reasons that additional study of Sully's Hill might/might not be worthwhile. (One reason a student might give for additional field study of Sully's Hill is the desire to observe the big vertebrates at twilight and dawn as they go to watering places.)

V. Materials needed: Altimeter, reference books and field keys, binoculars

LESSONS INVOLVING COUNTY AGENTS AND RESOURCE AGENCIES

County agents are usually located at the county court house. It has been my experience that in personally visiting with the agent some days ahead of the scheduled field trip I was able to insure a worthwhile day. Though I always contacted the agent ahead of my personal visit by phone or mail, the personal contact seemed to give him added knowledge about the aims of the particular phase of the class study.

Sample Lesson 16: Knowledge of Cultivated Crops and Domestic Lifestock Suitable to a Particular Area

I. Aim

- A. To learn that much information is available to both rural and urban citizens of any county through the county agent
- B. To learn especially of the cultivated crops and livestock suitable for the county in which the class is being conducted

II. Approach: Probably reference to the county agent will bring a variety of reactions. Most students, or their parents, have had some contact with him and most of this contact has been favorable in my experience. Few realize the many services he is willing to perform, including suggesting landscaping for rural homesteads

III. Procedure: Invite county agricultural agent to give combined lecture and field trip to various sites including, perhaps, the farms, ranches and homesteads of those students who may offer their lands as part of this field trip. Most agents are willing and able to conduct such a class field trip, and it is a learning experience for the teacher as well as the students

- A. Cultivated crops of the area
  - 1. Reasons these particular crops are grown
  - 2. Problems with these crops
    - a. Water availability
    - b. Insect pests: good and bad effects of pesticides
    - c. Fertility of land

- B. Landscaping of home sites both in town and on farms or ranches volunteered by students
  - 1. A number of alternative suggestions by county agent on plantings at various places around the homestead will probably be given
  - 2. Pamphlets describing various types of plantings and their suitability for different environments should be available for the students: NDSU prints these

- C. Establishment of windbreaks
  - 1. Places where they are most beneficial
  - 2. Types of trees and shrubs ideal for various areas; cost of each kind of planting both for town and country through county extension services

3. Additional benefits in creating a man-made habitat for wildlife

IV. Materials needed: Each extension agent has information on all types of landscaping, windbreak plantings, cultivated crops and other material pertinent to plants that may be successfully cultivated in the area in which he works. He should be contacted several weeks to a month before the students will be ready for this trip. A date (with an alternate date in case of rain) should be scheduled, which will give him sufficient time to obtain pamphlets and other materials which will reinforce the field observations. These materials are almost always free but be certain the county agent will have an ample supply for the class.

Sample Lesson 17: Birds of North Dakota and the Central Fly-Way

I. Aim: To gain a greater insight into methods of studying North Dakota's wild creatures in their relation to the environment at the Northern Prairie Wildlife Research Station, Jamestown, North Dakota

II. Approach

A. Reference to the need to protect and increase North Dakota's wildlife and the research being done at Jamestown for that purpose
B. A variety of articles written by biologists at the Research Station

III. Procedure: A two-hour educational tour was planned with one of the staff members at the Research Station after I had corresponded with him, explaining to him the aims of the course, and of this particular field trip

A. Slide film and lecture introduction to the research of the Northern Prairie Wildlife Research Station, which is the study of the breeding bird and migratory bird populations of the central fly-way

B. Tour of the building and field facilities

1. Explanation of the laboratory work in process
2. Examination of the library, its facilities, and the reprints available to the public
3. Tour of the bird pens and examination of mature stock
4. Tour and explanation of the hatchery facilities

C. Summary of trip in lecture room

1. Discussion of ways in which this class trip was closely related to previous study of the environment

2. Discussion of the ways in which the research being done at the Wildlife Research Station was directly related to today's concern for conservation and wise use of wild life

IV. Materials and preparation: The teacher and staff of the wildlife station should have carefully prepared this lesson on a date convenient to both groups. Students need little aside from bird keys and state maps for orientation.

Sample Lesson 18: The development and cultivation of domestic tree stock for North Dakota's windbreaks at Denbigh Tree Nursery and Towner Tree Plantation

I. Aim

A. To broaden student knowledge of the place of windbreaks in maintaining topsoil and providing wildlife habitat
B. To introduce the science of tree breeding, seed germination and selection of stock which will withstand the climate of the northern Great Plains

II. Approach: Reference to the great number and variety of windbreaks seen throughout North Dakota. How many rows of trees form a windbreak? What purposes do the windbreaks serve?

III. Procedure: Tour of the seedling nursery near Towner and the Denbigh tree plantation. This should be conducted by one of the foresters from the Bottineau school of forestry and should be planned with this person to make the best possible use of the field trip time.

The forester in charge of the nursery and plantation makes frequent trips to both areas. The instructor should arrange to meet him there well in advance of the day for which the class trip is scheduled. It is one of the services of the School of Forestry to explain their work to citizens of the state, but unless the instructor has made the trip before he takes the class neither he, nor the forester, will be certain what points to stress, or areas to see, during the allotted time.

A. Previous to the trip students can be given hand-outs which describe purpose, lay-outs, and plantings of both the nursery and plantation. These are prepared by the School of Forestry.
B. Students will probably have many questions to ask during the tour. They have been raised in windbreak regions.

IV. Assignment: Outline of a farm or ranch, real or imaginary, for a specified part of the state which would incorporate the uses of the shrubs and tree plantings best suited for each part of the area, including the land surrounding the home and buildings

V. Materials and preparation

A. Descriptive materials available from the State School of Forestry
B. Tree and plant keys
C. Planning between instructor and forester which will determine major topics to be included, purpose of field trip, and a date that is agreeable to all

APPENDIX D - ROADLOGS

Natural Science Roadlog for the Standing Rock Indian Reservation
(total distance about 44 miles)

Cumulative Distance	
	Begin trip at Fort Yates Post Office. Drive west out of town over glacial sediment and alluvium (stream-deposited material) onto a flat Missouri River terrace. The river flowed over this surface at some time in the past 10,000 years, depositing a layer of gravel.
0.9	Gravel pile south of road. This terrace gravel is about six feet thick and overlies lake sediment that was deposited in a lake that formed when the valley was dammed by glacial ice. Apparently the river that was dammed to form the lake was a north-flowing one, part of the regional preglacial drainage pattern. Why does the Missouri River flow south today?
1.8	Turn north (right) on State Route 24. Continue driving over the Missouri River terrace deposits. The bluffs to the west are composed of sandstone of the Fox Hills Formation.
2.8	The cattails on either side of the road in the ditches indicate a high water table.
3.4	Pelican Inn. Look to the west and notice how the trees are restricted to gullies cut into the Fox Hills Formation These gullies are partially filled with washed-in material that retains moisture more efficiently than does the bedrock.
4.6	Climb hill and drive off low terrace onto Fox Hills Formation.
4.9	Notice the boulders at the corner on the west. These are erratics that were transported to the area by glaciers. Are the erratics older or younger than the underlying Fox Hills Formation?
5.5	Crest of hill. The hills on the west horizon are composed of Hell Creek Formation.
6.7	Turn west (left) on paved road. The valley to the right through which Porcupine Creek flows is a melt water trench that carried water along the south edge of the glacier. As much as 200 feet of alluvial fill has been found by test drilling in the valley. At the time the valley was cut by glacial melt water, the Missouri River was not yet in existence and Porcupine Creek continued southeastward across southwestern Emmons County.
7.1	Yarrow on the north side of the road is most common on poor soil.

7.7 STOP 1. Roadcut on south (left) side of road exposes glacial lake deposits and Fox Hills sandstone. Can you identify each of these lithologies? The lake sediment is only a few feet thick and occurs only on the face of the roadcut. Fox Hills sandstone is beneath. Can you explain why it occurs only on the face of the cut? Notice the fine banding in the lake sediment. Can you find places where this bedding is contorted due to slumping and sliding that took place when the lake was in existence? Apparently, a lake formed in Porcupine Creek valley when a glacier that advanced somewhat later than the one that formed the valley blocked the valley causing water to back up, much as Lake Oahe backs up into the valley today. This lake probably dates to the time the Missouri River Valley in this area was cut.

9.2 STOP 2. Hilly area. What material forms the hills? These hills are really dunes. Can you locate their source area, where the material that formed them came from? The vegetation on this dunal area is typical of such areas: wild onions, roses, and wolfberry are common.

10.0 Road curves to the west. What plant is covering the valley floor? This plant is an indicator of a high water table.

10.6 Gravel road to right. Continue straight. Notice the change in vegetation as you climb out of Porcupine Creek valley onto the Fox Hills upland. The Fox Hills Formation is exposed in roadcuts for the next three miles.

11.9 STOP 3. Exposure of Fox Hills Formation. The brown band contains abundant carbonaceous (carbon-rich) material as well as abundant chips of petrified wood. Notice the fault in the almost vertical band. Try to think of reasons for the fault.

13.1 Notice the wolfberry and sage in the valley.

13.7 STOP 4. Brown, carbonaceous shale of the lowermost part of the Hell Creek Formation, which overlies sandstone of the Fox Hills Formation. Dig in both formations. The Hell Creek shale is almost a lignite although it contains too much nonorganic material to burn. You may find a few poorly preserved leaf fossils by careful crosswise splitting of pieces of the shale. What kind of an environment do the leaf fossils imply?

14.1 Notice the brush in the draw. What correlation can you draw between water supply and plant height?

14.2 Exposure of Hell Creek Formation on the north (right). The Hell Creek deposits form badlands topography wherever erosion is sufficient. Notice the iron and manganese-rich purple and brown debris at the base of the slope.

14.7 Watch for a pair of great blue herons in the stream to the left.

14.9 Notice the white-faced, black cattle in the field to the north, an Angus-Hereford mixture. White-face is dominant over black-face in a 1:20 ratio, while black pelt is dominant over red pelt in about the same ratio.

17.4 All the rock exposures in this area are of the Hell Creek Formation. South of the road about a mile are the Porcupine Hills, which are covered by a resistant layer within the Cannonball Formation, which overlies the Hell Creek beds. The upper part of the Hell Creek Formation is about 105 million years old and contains abundant dinosaur fossils, particularly in southwest North Dakota. The overlying Cannonball Formation is only about 65 million years old and it contains no dinosaur fossils. Why are there no dinosaur fossils in the Cannonball Formation?

The yellow and blue flowering plants are alfalfa, planted for hay. They do well with sufficient water. The land is poor for crops such as wheat, due to the underlying Hell Creek Formation, which forms mineral-deficient soils.

18.4 Notice the pediments (flat erosion surfaces) at the north end of the Porcupine Hills south of the road. Notice the trees. What do these naturally growing lines of trees mark? Why do they choose these places to grow, rather than areas several rods away?

18.7 Junction with State Route 6. Turn north (right), continuing over sandstone of the Hell Creek Formation.

19.2 Road to Shields. Continue to the north.

20.2 What can you infer about water conditions in this area? Notice the hayfield.

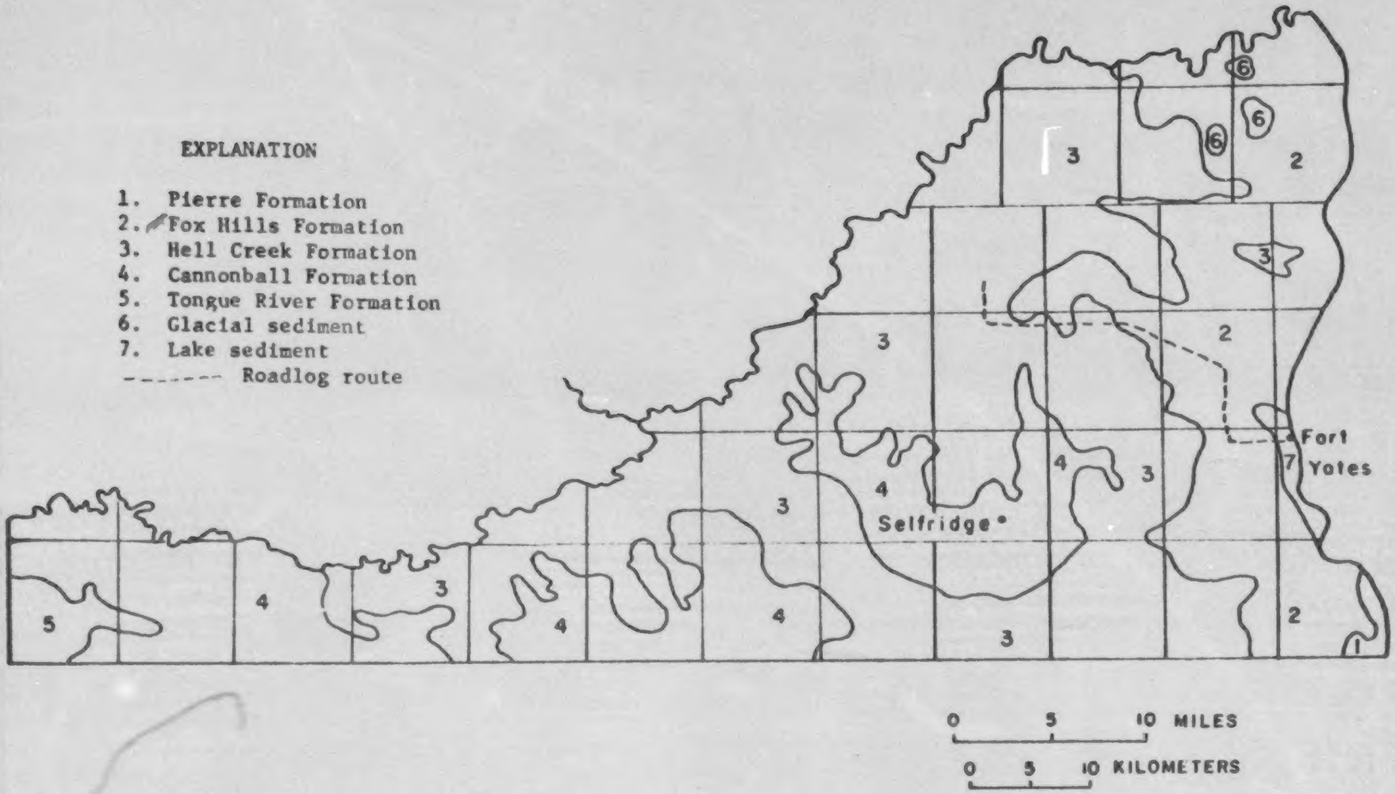
21.0 STOP 5. Badlands developed in the Hell Creek Formation. The bare slopes here allow erosion to proceed rapidly. Notice the bands of vegetation that follow moist horizons in the rock. The dark colored debris on the surface is weathered siderite, iron carbonate. Large numbers of concretions can be found and careful searching may turn up dinosaur bones. Cattle bones are also common so be careful to observe the conditions under which you find the bones. Write in your notebook your observations on the bones, where you found them, and other information that will later help you to identify your "find." If you have a camera, photograph a fossil before and after removing it.

Petrified wood is common. These fossils help us to understand the environment under which the sediment was deposited in Cretaceous time. The climate was warm and moist, something like that in the Everglades of Florida today. Streams flowing over the area deposited the sand, and dense forests grew in the nearby lagoons.

Notice the "pipes" and "caves," both the result of water erosion. Water rushing down the slopes carves out hollows in the sandstone. These hollows broaden downward as the water flows through them. Tunnels are also common in the gullies and mudflow deposits can be seen in a few places. All these features indicate the rapid rate of erosion in this area.

The vegetation in the area is typical of desert badlands; sage, cacti, lichens, and sparse grasses. Notice how erosion is retarded wherever plants are established. On a summer day the temperature in this area may reach 50° C (122° F) when surrounding parts of the area are 30° C (86° F). What reasons can you give for the temperature differential?

End of trip. Return to Fort Yates.



EXPLANATION

1. Pierre Formation
2. Fox Hills Formation
3. Hell Creek Formation
4. Cannonball Formation
5. Tongue River Formation
6. Glacial sediment
7. Lake sediment

------- Roadlog route

1
2
3
4
5
6
7
Selfridge
Fort Yates
0 5 10 MILES
0 5 10 KILOMETERS

Figure 6. Geologic map of the Standing Rock Sioux Indian Reservation showing the field trip route.

Natural Science Roadlog for the Turtle Mountain Indian Reservation
(total distance about 23 miles)

Cumulative
Distance

Begin trip at parking lot, west side of C. A. P. Building in Belcourt. Drive west on North Dakota State Highway 5 and U. S. Highway 281. This area is largely gravel, stream sediment that was deposited by a large stream flowing from the Turtle Mountains at the end of the ice age. For about the first four miles you will be driving over thin gravel. The highway follows a broad valley, which heads near Lake Belcourt (Fish Lake), southwestward for about four miles. The first two miles are slightly rolling gravel deposits, collapsed outwash that was deposited, in part, on top of stagnant glacial ice. Glacial sediment (till) is found in some places in the valley where the ice was particularly thick, preventing gravel from being deposited.

At the time the valley was cut and the gravel was deposited, the Turtle Mountains were covered by a relatively continuous layer of stagnant glacial ice. The ice, in turn, was covered and thereby insulated by a layer of glacial drift: sand, clay, boulders, etc. Rainfall on this area was great, much more than it is today, and the large amount of runoff along with the melting ice, resulted in the river that deposited the gravel here.

1.2 Notice the silverberry bushes growing naturally in the field to the left. This shrub is found on the edge of the grassland ecosystem in draws or places of higher precipitation.

1.3 (Mileage marker 240). Exposure of glacial sediment (till) in the roadcut on the north (right).

2.3 (Mileage marker 241). Notice that the valley is better-defined here and you can easily identify both its walls. The highway is built along the north valley wall. To the right, on the south-facing slopes of the hills are silverberry, wild rose bushes, and higher on the slopes (where precipitation is somewhat greater) or in the draws (where the water table is closer to the surface), taller trees grow. Notice boxelder, green ash, aspen, and balsam poplar.

2.9 Highway curves westward, to the right up onto a till surface. In about a half mile, the highway will once again drop into the valley.

3.9 Exposure of glacial sediment in the roadcut on the north.

4.8 Exposure of lake silt in roadcuts on either side of the highway. The light yellowish brown silt was probably deposited in a lake dammed between the high land on the north and glacial ice on the south. Such lake silt deposits are widespread along the southern edge of the Turtle Mountains in this area. Apparently, the Turtle Mountains were free of glacial ice while the lowland to the south was still subject to glaciers. The lakes formed at the juncture of these glaciers and the Turtle Mountain plateau.

6.1 Exposure of lake silt in ditch.

7.3 (Mileage marker 246).

7.5 Turn north onto gravel road toward St. John. Can you identify the different species of willows in the ditch to the left? Salicilic acid (used in aspirin) is found in willows and willow bark. Cattails are to the right.

7.8 Climb into the Turtle Mountains. You are driving into dead-ice moraine that is typified by rugged, undrained topography. Potholes are abundant. Their presence makes dead-ice moraine our main nesting area for wild ducks. The potholes represent areas where the stagnant ice was slightly thicker than surrounding areas. When the ice melted, a depression resulted. Conversely, where the ice was thin, the overlying material remained in a relatively high position when the ice melted and hills and ridges developed in these places. The remainder of the trip is over dead-ice moraine.

8.0 STOP 1. Small pit on the east (right). Silt that was deposited in a lake dammed at the edge of the Turtle Mountains is exposed here.

8.5 What plants are growing here that one doesn't find on native prairie?

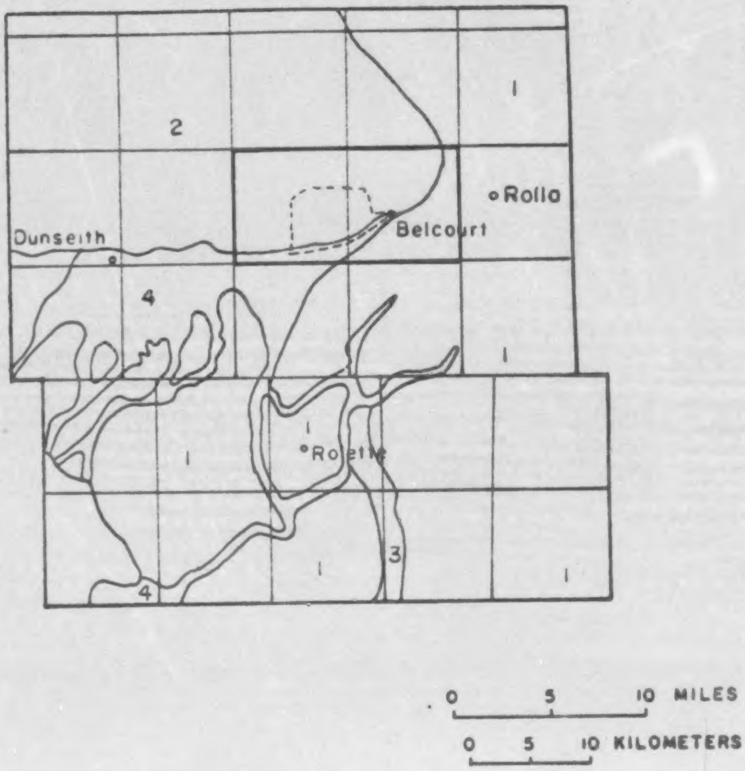
8.6 Exposure of interbedded lake silt and till.

8.9 MDTA Training Center sign. The stones in the sign are glacial erratics, largely igneous, granitic rocks that were carried to this area from western Ontario by glacial ice.

9.4 Small pond on the right. This area is typical dead-ice moraine. The Turtle Mountains are an outlier, an erosional remnant of Paleocene bedrock that is covered by glacial drift, the surface expression of which is dead-ice moraine such as this. The bedrock, Tongue River Formation, is buried everywhere beneath 200 to 300 feet of glacial sediment. The Tongue River Formation is known only from test drilling in this area. The presence of the bedrock hills caused the glacier to "stall" as it flowed over the area, thus resulting in stagnation. Continued movement of the glacier to the north, east, and west of the Turtle Mountains resulted in large amounts of glacial debris (sand, silt, clay, and boulders) being deposited on top of the stagnant ice. Later, when the stagnant ice melted, dead-ice moraine resulted.

9.6	Jackrabbit Road. Continue northward.
10.0	Lake on both sides of the road.
10.3	Note cutgrass (a sedge). Also note horsetails. Both stages of horsetails can be seen from July onward.
11.2	Note "extinct lake" on both sides of the road. Land is swampy at times of high rainfall and water-loving plants such as cutgrass and cattails grow here.
11.8	Dunseith Indian School road. Continue northward. Throughout this area Kentucky bluegrass and yellow clover, a legume, thrive. Both are introduced plants.
13.3	Road curves to the northeast. "Extinct lake" on the right.
14.0	Road curves to the east. Notice the horsetails in the lake on the left, sedges in the lake on the right.
14.1	Dark brown clay may be visible in the roadcut on the left if vegetative cover is not thick. This clay, which is sticky, heavy, highly organic material, was deposited in a lake that was entirely surrounded by glacial ice. When the ice melted, the clay deposit was left in an elevated position. Such deposits are known as "elevated" or "perched" lake plains.
14.5	Lake on the left. Notice the several successive zones of vegetation.
14.7	STOP 2. St. Benedict's Catholic Church. This is a good place to stop and walk around, observing the various trees such as aspen, balsam poplar, oak, and green ash. Spruce have been planted for ornamentation.
15.3	Till exposed in cuts on either side of the road.
15.5	STOP 3. Lookout tower. Elevated lake deposit, dark brown, organic clay, exposed on the main road just east of the road to the tower.
15.7	STOP 4. Till exposed in roadcut just below the lookout tower.
16.0	Notice the dead trees in the lakes on either side of the road. Can you explain the reason why?
16.1	Brownish till and dark gray lake sediment exposed in the roadcut on the left.

19.5	Belcourt Lake.
20.1	Lake with submerged car on the right. Continue southward.
21.1	Intersection. Continue southward. Notice the dark gray lake sediment, an elevated lake deposit, at the corner.
21.4	Till exposure on the west (right).
22.1	Junction with Jackrabbit Road. Stop. Turn east toward Belcourt.
22.4	Junction with highway. End of roadlog.


2
1
Rollo
Belcourt
Dunseith
4
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1
Rolette
1
3
1
1
4
0 5 10 MILES
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EXPLANATION

1. Ground moraine
2. Dead-ice moraine
3. End moraine
4. Outwash deposits
5. Lake deposits

------- Roadlog route

Figure 7. Geologic map of Rolette County showing location of Turtle Mountain Indian Reservation and field trip route.

Natural Science Roadlog for the White Shield Area
(total distance about 32 miles)

Cumulative Distance	
	Start trip at White Shield School, driving south from the school on the paved road. For approximately the first three miles you will be on glaciated bedrock topography. The cover of glacial drift in this area is only a veneer. Notice the presence of a few boulders on the surface, conclusive evidence of glaciation.
0.9	White Shield Complex on east side of road.
1.1	Turn east (left). Notice the plowed fields, or stubble in winter and the growing wheat in early summer. Large irrigators in the field ahead use water from wells drilled to glacial deposits, aquifers composed of sand, gravel, and sandy till. The water table is close to the surface here and, in some places, ponds indicate that the water table is intersected.
2.4	STOP 1. Enter the shelterbelt to the east (left). Can you identify Douglas fir, blue spruce, boxelder? What other trees and shrubs do you find? Which of these could have been taken from beside neighboring streams? Which do not grow naturally in McLean County? Shelterbelts provide natural shelter for wildlife. In winter, try to identify animal tracks you see. In summer, watch for these birds (and their nests): western meadowlark, eastern kingbird, red-winged blackbird, lark bunting, chestnut-collard longspur, field sparrow, bluejay, and brown thrasher.
2.5	Broad, low area. Note the presence of willows, cottonwoods, and other water-loving plants throughout this low area. They are indicators of a water table that is close to the surface.
3.1	Turn north (left) on gravel road.
3.2	Drive down into the broad, poorly-defined valley of the West Branch of Douglas Creek. This valley, or sag, apparently coincides with an ancient preglacial feature, perhaps a valley that carried a large stream before the area was glaciated. Several sloughs and lakes, including Blackwater Lake, occur in the sag. The glacial drift cover is much thicker in the sag than on the uplands to the north and south.
4.9	Road curves to the northwest (left).
5.0	STOP 2. This is an excellent place to study natural history because it is native, although grazed, prairie. The cattle in this field grow fat on such mid-grasses as little blue-stem,

needlegrass, June grass, prairie dropseed, and side-oats grama. An introduced grass, Kentucky bluegrass, also grows here. These grasses ripen, or cure, on the stem. The buffalo that filled the biological niche now occupied by cattle used these same grazing lands.

Besides grasses, can you identify plants such as salsify, prairie rose, and Woods rose? Can you find members of the pea family (legumes) such as Indian turnip, clover, (an introduced plant) and some of the sages?

This slough is a small pothole, formed when a block of buried glacial ice melted, causing the overlying materials to slump beneath the level of the surrounding land. Note the cottonwood trees and willows on the shores. Red-winged blackbirds live among the cattails at the pond's edge. The area north of here is part of an end moraine that formed at the margin of the glacier. The glacier covered the area north of here and its margin trended northeastward from here. Notice the change in topography as you drive over the end moraine. The closely-spaced, small hills are the result of materials being dumped at the edge of the glacier.

4 STOP 3. Road straightens to the north. Notice the increased abundance of surface boulders and the hummocky terrain, both typical of end moraine. Stop at the small knob on the right to look at an exposure of typical glacial sediment (till). Notice the variety of textures ranging from clay-sized particles to boulders.

2 Turn west (left) on McLean County Road 6. To the southwest is the broad sag we have crossed. Notice the rugged relief on the Hill farm to the northeast.

9 STOP 4. Small road cut on the right exposes glacial lake sediment. The lake, a small one, was dammed in contact with the glacier and it drained when the ice melted. Notice the nearly horizontal bands in the lake sediment.

3 Pothole lake with almost vertical banks. A large piece of glacial ice was buried here under an overlying blanket of glacial sediment and when the ice melted over a period of perhaps two to three hundred years, the overlying load of sediment collapsed, forming the depression that you see. Because the depression interects the water table, a lake fills it.

3 Highway. Continue to the west. This flat area is a plain formed in a lake that filled this part of the sag (mile 3.2) during the glacial epoch. The lake probably covered about three square miles. Bedded silt, similar to that exposed at Stop 3, covers most of the lake plain. Notice the lack of boulders on the surface of the lake plain.

8.7 Drive off lake plain onto ground moraine. Ground moraine consists of glacial sediment, mainly till, that was deposited beneath the moving glacier.

9.2 Till exposure on the right.

12.9 STOP 5. Paint Hill. This large hill of sand and gravel was formed by water flowing from the ice into a hole in the glacier. Such hills are sometimes called "kames," but this rather flat hill is not typical of kames, which are normally cone-shaped. Inspect the gravel in the pit north of the road. Shale is common in the gravel. The gravel is rather "dirty" and poor in quality.

Walk about the grassy area near the top of the kame. Note the native grasses. Can you identify the wildflowers that you find? These are deep-rooted, flowering herbs, called "forbs" by ranchers. Depending on the season, you will be able to find coneflower, prairie clover, wallflower, wild indigo, red mallow, vervain, brown-eyed Susan, fleabane, boneset, ironweed and many species of sunflowers, asters, and goldenrod. Many Indian turnips grow here. Harvest these in July.

Rocks of many sizes are found here. Turn some of them over. Examine the white substance, "caliche" (calcium sulphate and calcium carbonate), found on the undersides. This is formed when rain flushes the tops of the rocks, allowing ground water to deposit dissolved minerals on the undersides of the rocks.

13.2 Note kettle hole. No lake is present because the water table is not intersected.

17.4 Turn south (left).

18.4 Turn west (right).

19.1 Turn south (left).

21.1 Highway. Continue to the south.

21.5 Shelterbreak of cottonwood and boxelder trees. Where did these trees come from?

22.5 What killed the cottonwood trees in the small lake behind Buffalo Rock Hall? Note the trend of this lake. It is an old river channel that intersects the water table.

23.9 Turn southeast.

24.2 Note buffaloberry bushes, with their long thorns, and the Woods rose bushes, with much smaller thorns. Both the prairie rose and the Woods rose grow in this area. The latter is a deeper pink and grows on a much bushier plant.

24.4 Leave the main road and continue on the narrower road to the southeast into the "breaks" of the Missouri.

If you are following this field trip during the breeding season, you will already have seen many different species of birds. The area ahead has a great diversity of native species because 1) except for grazing cattle, the land is undisturbed, and 2) there is a great diversity of micro-climates. On this land you can find marshes, mid-grass prairie and short-grass prairie, thickets of buffalo berry, wolfberry, roses, and taller thickets of box-elder, black ash, and elm. Lake Sakakawea has many species of birds found on large mid-continent lakes in the temperate zone. Among the birds that have been identified in this area are the mourning dove, killdeer, sparrow hawk, Hungarian pheasant (imported), upland plover, yellow-shafted flicker, western kingbird, barn swallow, bluejay, black-billed magpie, bobolink, western meadowlark, red-winged blackbird, lark bunting, field sparrow, and chestnut-collared longspur.

24.7 Enter pasture to south (right). Note the silvery covering on many species of plants. This is a protective device evolved in the plants to prevent water transpiration and is an indicator of arid country. Farther west the skin of cacti is waxy, and offers an even greater resistance to water loss due to transpiration.

24.8 STOP 6. Some of the glacially-deposited red rocks in this area contain deposits of iron. Also in this area you will begin to see pebbles of scoria. Usually these are flat, or angular, in contrast to the glacially-polished boulders and smaller stones that are found here and at other places we have stopped. Scoria deposits will be seen in place when we reach the banks of Lake Sakakawea.

Note the higher shrubs and trees that mark the water courses. Why are there no cottonwood trees in this area?

25.9 STOP 7. Collect cattails from this pond. In the spring, the root tips of the cattails are delicious when boiled with salt and butter added. They taste something like cucumbers when raw.

26.3 The buckbrush growing beside the road is commonly infested with worms. Can you identify them?

27.0 Badland topography to the south (right) is carved from the Sentinel Butte Formation. "Badland" comes from the French "Les Mauvais terres a'traverser," which was the French translation of the Lakota "Macosica" meaning "bad land to travel across."

28.0 Enter gate and continue following path. We are travelling through native prairie that has been heavily grazed. Can you give possible reasons for the circular patches of buckbrush?

Watch for gray partridge, common in this area. Two turkey vultures claim their territory above Nishy Bay ahead of us.

32.0 STOP 8. Leave cars on lane. Walk southwest over the native prairie down to the inlet of Lake Sakakawea. Note the varied types of grasses growing in response to micro-climates caused by such physical factors as the amount of sun exposure of various areas and the amount of moisture retained by the soil. As you approach the bay notice the outcropping Sentinel Butte Formation. It is composed of layers of sand and sandstone, silt, and claystone, lignite, and ash with scoria above the ash left from the burned lignite.

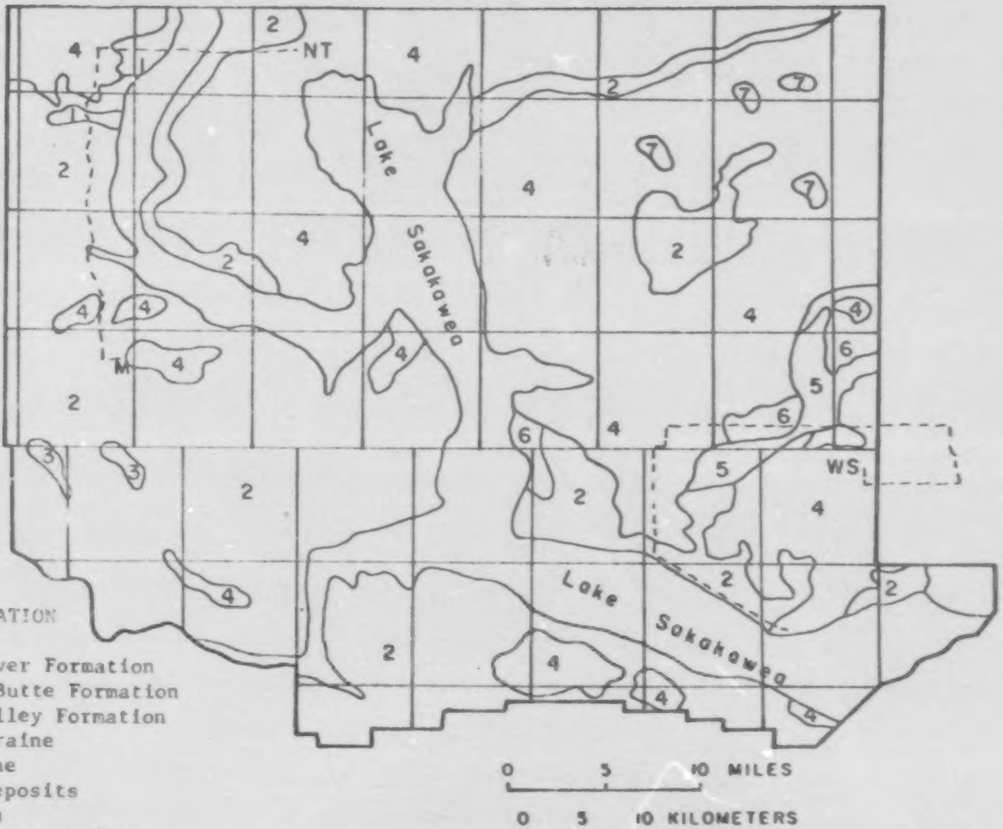
Lignite is economically important to North Dakota, and it also holds water. On the hill directly above some of the lignite is a growth of wolfberry, which requires more subsurface water than does the mid-grass that is directly above the surrounding outcropping scoria. It is not known whether there is a direct correlation between the lignite and the presence of the moisture-demanding shrubs on the slopes above it, but the relationship suggests that there is. Note the different colors of the scoria in the Sentinel Butte Formation. Also note that it overlies a layer of ash that can be correlated to the lignite in the same formation. When the lignite burned, it turned to ash, and at the same time baked the clay above it into a natural brick. The ash occupies only a few inches, but the unburned lignite is several thick thick. Burned areas, therefore, are somewhat slumped.

On the shores of this inlet are many large angular pebbles of scoria-bearing leaf imprints. What other water-washed materials do you find here? How can you tell if they come from some distance or perhaps fell from the overhanging cliffs? Look for strand lines on the sandy beach.

There have been prairie rattlesnakes on both sides of the Missouri River beyond the memory of man, but the prairie rattler on the east side had generally stayed on the river floodplain until his habitat was destroyed. With the damming of the Missouri River and the formation of Lake Sakakawea, the prairie rattlesnake retreated to higher ground, and now breeds fairly close to human habitations. A man was bitten in Garrison, North Dakota, in 1972. Large numbers of the hibernating snakes were removed from a den at Good Bear Bay, about twelve miles southwest of White Shield in McLean County, in winter, 1972. We have seen their skins in an abandoned churchyard seven miles south of White Shield, and also in the Douglas Creek Public Use Area along Lake Sakakawea, in McLean County. The rattler senses vibrations and will avoid approaching footsteps if he has time to escape. In areas infested by these snakes, it is a good idea to walk slowly, but not stealthily, and let the snake discover you before you meet him.

As you leave the inlet, note the clumps of prairie grass whose roots have been unearthed by the eroding waves.

End of trip. Watch for Pronghorn, which graze in the area. In early morning, or near sundown, you will probably see deer browsing. You may scare up a fox as you return to the paved road.


NT
M
WS
Lake Sakakawea
Lake Sakakawea
1
2
3
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5
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0 5 10 MILES
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EXPLANATION

1. Tongue River Formation
2. Sentinel Butte Formation
3. Golden Valley Formation
4. Ground moraine
5. End moraine
6. Outwash deposits
7. Lake plain

------- Roadlog route

Figure 8. Geologic map of the Fort Berthold Indian Reservation showing field trip routes.

Natural Science Roadlog Between Newtown and Mandaree
(total distance about 32 miles)

Cumulative Distance	
	Begin trip at the junction of North Dakota State Highways 23 and 1804 in Newtown. Drive west on 23. Notice the numerous exposures of Sentinel Butte Formation that can be seen along the highway.
1.7	Mileage marker 48. Large granite boulder on the north side of the highway. This is a glacial erratic that was carried here from Ontario by the glacier. Notice how the introduced grasses, sweet clover, and native rabbitbrush and sage over the roadcuts along the highway help to keep the soil in place.
1.9	Several glacial erratics on the ridge north of the highway.
2.1	Notice the slumping in the banks along the highway. Such slumping results when the roadcuts are constructed too steep.
2.7	Road to historical marker to the north at mileage marker 47. Drive to the top of Crow-Flies-High Butte, taking note of the glacial erratics on the road up the hill. STOP 1. Historical marker sign at the top of the butte is made of many different types of field stone, all glacial erratics. They include igneous, metamorphic, and sedimentary rocks such as granite, gneiss, and limestone. All of these rocks were carried here by glaciers from sources in Canada. The large boulder at the top of the parking lot is partly metamorphosed granite. The Missouri River (now Lake Sakakawea) at this point makes a turn southward. It flowed eastward through the broad, low sag north of the observation point before it was diverted to its present route by the glacier. Glacial drift, till, and gravel block the old route of the river, which continued past Newtown and through what is now the Van Hook Arm of Lake Sakskawea. Return to the highway. Notice the hard, boulder-like concretions in the bedrock on the south side of the road at mile 47. Notice too, how cottonwood trees, buffaloberry, wolfberry, and other shrubs mark the watercourses.
2.9	Lignite coal exposed on the left.
3.1	East end of the Four Bears Bridge over Lake Sakakawea.
4.0	West end of the Four Bears Bridge. The gravel on the north was deposited on the terrace you are now on while the Missouri River was being diverted.
4.7	Good exposures of bedrock along the highway. Notice the crust of sodium sulphate salt that forms on the surface in dry weather.

5.2	STOP 2. Abundant glacial erratics. Thin glacial drift lies on the bedrock topography in this area. Headward erosion from the Missouri River accounts for much of the relief. In the field to the south (left) is native shortgrass prairie. Can you identify the grasses? What other native grassland plants do you find? Can you identify some of the introduced species?
10.0	Antelope Oil Field. This is part of the Nesson Anticline, which is North Dakota's most important oil-producing area. Oil is produced in this area from three horizons of Mississippian and Devonian age. Wells range up to about 10,000 feet deep. As of January 1, 1974, over 26 million barrels of oil and over 47 billion cubic feet of natural gas had been produced from the Antelope Field. Notice the scoria road metal in the area.
10.8	Junction of Highways 22 and 23. Turn south on Highway 22. Mileage marker 157. As you drive southward on Highway 22, you will cross several deep valleys, all of which were formed by headward erosion from the Missouri River trench.
11.4	The buttes on the southern and southwestern horizons are outliers of hard sandstone of the Golden Valley Formation, which lies on top of the Sentinel Butte Formation.
13.3	Begin descent into Clarks Creek Valley. Notice the exposures of Sentinel Butte Formation in the roadcuts and the badlands topography in the valley. The popcorn-like surface in places is caused by a loose surface mulch that develops when the bentonitic clays shrink as they dry.
14.3	Cross Clarks Creek. Can you identify the boxelder, ash, maple, and elm trees?
14.5	Lignite exposures on the left.
14.7	Massive, hard sandstone exposure on the right.
15.1	Drive onto the upland again. The prairie is farmed to the east and almost undisturbed on the west.
15.7	Begin descent into the valley. Notice the tubular, orange-colored channel sands of the Sentinel Butte Formation to the east.
15.8	STOP 3. Mileage marker 152. Park the car in the ditch and walk down into the valley. Look for the birch trees. Notice also the elm, willow, oak, boxelder, and aspen trees in the valley. On the east look for iron concretions.
15.9	Channel sand deposit on the left.
16.8	Scoria exposure on the right. Notice the color contrast between the sage and the trees.

19.8 Mileage marker 148. Blue Butte on the left. Large boulders of sandstone that have fallen from the caprock on top of the butte lie on the butte slopes. The caprock on this particular butte is apparently a channel sandstone of the Sentinel Butte Formation. The top of Blue Butte is approximately 400 feet above the highway.

21.5 Begin descent into Bear Den Creek valley. Notice the good exposures of sandstone on the way down. Notice how the vegetation pattern is controlled by various zones in the slopes. On the right how many trees can you identify? Why are they so large in this area?

22.4 Scoria exposed on the left.

22.6 Lignite exposed on the left

23.1 Landslide area.

23.5 Bridge over Bear Den Creek.

24.0 Notice the exposures of Sentinel Butte Formation bedrock in the badlands topography of the valley ahead.

25.0 On the roadcut to the east, notice the plants, especially sage, beginning to grow on the fresh roadcut.

26.2 Junction of North Dakota Highways 22 and 73. Continue southward.

29.2 Cross-bedded sandstone.

29.6 Turn east toward Mandaree.

30.1 Occasional glacial erratics occur in the fields here. This area has scattered patches of thin glacial till on top of the bedrock. The area is near the edge of the early Wisconsinan glacial limit. The early Wisconsinan glacier apparently advanced as far as the Little Missouri River, about 10 miles to the south, although it covered broad areas southeast of here. Prior to the advance of the glacier, the Little Missouri River flowed north into Williams County, but the glacier diverted it eastward.

30.9 Turn south into Mandaree.

31.4 School. End of roadlog.

Natural Science Roadlog for the Devils Lake Sioux Indian Reservation
(total distance about 29 miles)

Cumulative Distance	
	Begin trip at the Seven Dolors Catholic Church in Fort Totten. Turn south (left) on the gravel road across from the CYC building. As you drive south, you will gradually ascend the North Viking end moraine. The end moraine apparently marks the margin of the glacier while it extended southwestward from this area and northeastward to Sully's Hill.
0.3	Ascend onto the North Viking end moraine. The end moraine is greatly ridged, with most of the ridges trending from northwest to southeast, parallel to the direction of the ice margin in this area. The ridges probably represent individual blocks of material that were sheared by the ice from the material the glacier was flowing over and thrust up so that what you now see are the edges of the blocks. STOP 1. Stop at the top of the hill to look at the shelterbelt. Try to identify the several varieties of trees. Bird life is abundant in the shelterbelt.
1.5	Notice the hummocky topography, which is typical of end moraine areas. Notice the tree concentrations on the north-facing slopes. The more arid, south-facing slopes tend to lack trees.
1.8	First of several curves in the road. Ponds on either side of the road. A playa (ephemeral or intermittent) pond is on the north (left). Like all lakes, it has been gradually silting in and accumulating decayed plant material and within a few years it will be a hay meadow. STOP 2. Stop to look at the varieties of grasses and sedges that grow in the ponds.
3.9	Drive off the till of the end moraine onto an area of gravel. The ridge just to the west of the road is an esker that was deposited by a south-flowing stream in a crack in the glacier.
4.2	Dead end. Turn west (right).
4.3	STOP 3. Stop at the small gravel pit in the esker to look at the shaly gravel. Notice the bedding in the gravel and the many flakes of shale. The flat area to the southwest is also covered by gravel. It was deposited by streams that flowed from the glacier; probably the same water that deposited this esker deposited the gravel southwest of here after it had left the ice. The gravel area southwest of here is known as an outwash plain. Continue west as far as the gravel pit just

west of here.

4.6 STOP 4. Gravel pit in outwash deposits. Notice the bedding. The iron-stained coloration (reddish browns) is due to the presence of iron in the shale. Turn around and drive east.

5.1 Road to Fort Totten. Continue eastward over the gravel outwash plain.

5.5 You are driving back onto end moraine. Notice the cuts in till and the occasional boulders on the surface. Boulders are generally absent from the areas of glacial outwash gravels.

6.0 Glacial outwash. Notice the gravel in the roadcuts. This is partly collapsed outwash that was deposited on top of blocks of stagnant ice that later melted. When the ice melted, the overlying gravel, which probably originally had a fairly flat surface, slumped down resulting in the irregular topography you see here today. The numerous ridges suggest that streams flowed through cracks in the ice in this area. Because of the gravelly soil, which drains easily and doesn't retain moisture in dry years, there is a "burning" problem as the crops tend to dry up.

6.3 Road to Bouret Dam. Continue eastward.

7.5 Descent into Seven-Mile Coulee. This wide valley is a melt water trench that carried water from the ice in the vicinity of Sully's Hill, southward to the Sheyenne River. The unusual vegetation pattern in Seven-Mile Coulee is supported by a high water table. Notice several varieties of willows in the marsh and in the cattail swamp notice the red-winged blackbirds.

8.3 Drive out of Seven-Mile Coulee onto a gravel outwash plain. The surface in this area is slightly rolling, indicating that the gravel was deposited on stagnant ice in places.

9.4 Small gravel pit, north side of road. Notice the shaly gravel.

10.5 Drive up onto end moraine. Notice the many cuts in the till. The glacier was mainly east of here when this end moraine was deposited.

11.4 Lake on the south side of the road.

11.6 Notice the good exposures of till along the road. Considerable gravel is mixed in in places, indicating that considerable running water was present while this till was deposited.

12.2 Road to Wood Lake to the south. Turn north.

13.2 The large hill to the west is known as Devil's Heart. It is composed of gravel that was deposited at the northwest end of a large crack in the glacier. The crack widened southeastward, allowing the water to spread over a wider area and deposit an outwash plain that becomes extensive in the Warwick area.

14.3 STOP 5. Junction with east-west road. Turn east and cross the railroad tracks. Excellent exposures of till can be seen at the railroad crossing.

14.4 Road turns north, continuing over end moraine.

15.9 Road curves to the west around the lake.

16.4 Dead end road. Turn east.

16.6 Turn north.

17.2 Mission Bay to the west.

17.9 This rather flat area is ground moraine that is covered by till. It was deposited at the base of the moving glacier.

19.6 Junction with State Highway 20. Turn west. This area is part of the lake plain that was once covered by Devils Lake. The hill to the west marks the edge of the lake plain. Although this area was flooded, till is most common at the surface because the lake didn't last long here.

20.3 Drive back onto ground moraine.

20.8 Road curves northeastward.

21.2 Drive down off the ground moraine onto lake plain. Notice the abundant boulders that mark the former shoreline of Devils Lake.

21.3 Benson-Ramsey County line.

22.1 Railroad crossing.

22.3 Junction with State Highway 57. Turn south (left).

23.1 Devils Lake Sioux Indian Reservation. Ramsey-Benson County line. You are driving over lake plain that was flooded within the past 100 years.

24.6 Road to St. Michael. Continue on Highway 57. Gravel pits to the northwest are in beach deposits.

25.4 The road follows the lake around the north edge of Sully's Hill. It coincides in part with the former shoreline of the lake. The high relief to the south is part of Sully's Hill, which appears to be composed mainly of glacial till. Sully's

Hill is a huge block of material that was moved southward by the glacier from the depression now occupied by Devils Lake. Similar features are present elsewhere in North Dakota. In every case, a large block of material has been moved a short distance, usually less than a mile, by the glacier, resulting in a depression on the side of the hill from which the glacier came.

26.0 STOP 6. Good exposure of glacial till on the south side of the highway. Stop to look at the till. Notice the mixture of large and small pebbles and cobbles in a ground mass of silt and clay. Till was deposited at the base of the moving glacier and at its margin. It consists of materials that were carried in the ice and ground up within the moving glacier.

26.8 Good exposure of glacial till.

27.5 Good exposure of glacial till.

28.2 Good exposure of till overlying poorly exposed Pierre Formation shale. The shale is highly weathered and covered in most places by slump from above.

26.4 Road crosses part of the lake. Notice the boulders that have been piled along the road to keep the waves from eroding the road. These are glacial erratics, mainly chunks of igneous rock that were transported here from Canada by the ice.

28.9 Turn south toward Fort Totten. End of roadlog.

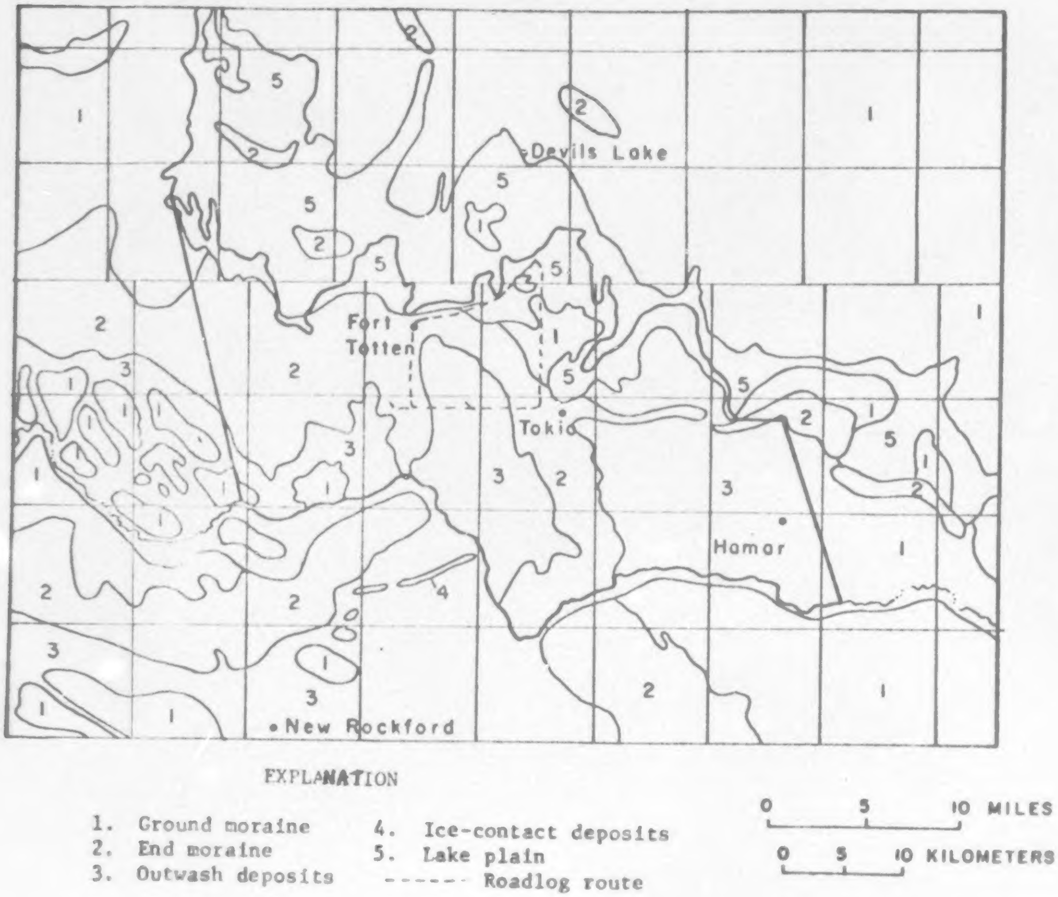
Devils Lake
Fort Totten
Tokio
Hamar
New Rockford
1
2
3
4
5
EXPLANATION
1. Ground moraine
2. End moraine
3. Outwash deposits
4. Ice-contact deposits
5. Lake plain
------ Roadlog route
0 5 10 MILES
0 5 10 KILOMETERS

Figure 9. Geologic map of the Devils Lake Sioux Indian Reservation vicinity showing field trip route.

APPENDIX E

ESTABLISHMENT OF THE NORTH DAKOTA INDIAN RESERVATIONS

In 1845, when the American Fur Company abandoned Fort Clark, it moved up the Missouri River to a place the Indians called "Like a Fish Hook" and built what was called Fort James. Hidatsa Indians, who had just moved there, assisted in the building project. The following year the fort was renamed Fort Berthold. About 1850, the Mandan and Hidatsa Indians moved to Fort Berthold and in 1851 the Fort Laramie Treaty was written, establishing a reservation for the Hidatsa, Mandan, and Arikara. Four Bears signed for the Hidatsa, Iron Bear for the Arikara, and White Wolf for the Mandan. In signing the treaty, the Indians did not abandon any claim they had to other lands, nor did they surrender the privilege of hunting, fishing, or traveling over any lands described in the treaty and assigned to other nations (Washburn, 1973).

In 1862, the Arikaras joined the Mandan and Hidatsa Indians at Fort Berthold. Members of the three tribes, all fearing the Sioux, built houses nearby in the traditional earthen dome fashion. In December, 1862, the Sioux destroyed the original Fort Berthold and the nearby Fort Atkinson became the company headquarters and was renamed Fort Berthold. President Grant in 1870 officially created the Fort Berthold Indian Reservation for Mandan, Arikara, and Hidatsa Indians (Washburn, 1973).

The Dawes Act became effective in 1887. It provided for parceling of lands to individual Indians. Rations and clothing, in addition to land, were to be distributed to the Indians. Between 1870 and 1910, executive and congressional actions reduced the reservation from

12,500,000 acres to 980,500 acres. Today, the reservation covers 930,560 acres (1,454 square miles) (U.S. Dept. Commerce, 1974).

The Indian Reorganization Act, accepted by the people of Fort Berthold in 1934, provided for tribal self-government under their own constitution and by-laws.

The construction of Garrison Dam between 1946 and 1956 and the resultant creation of Lake Sakakawea forced large numbers of people on the Fort Berthold Indian Reservation to relocate. Before the dam was built and the reservoir created, 90 percent of the reservation's population lived within the Missouri Valley, where the best agricultural land was found along with extensive areas of timber (Robinson, 1966).

Descendants of people from the Mandan, Arikara, and Hidatsa tribes made up the residents of the present day Fort Berthold Indian Reservation along the Missouri River in Dunn, McKenzie, Mountrail, McLean, and Mercer Counties.

The Fort Totten Indian Reservation (now known as the Devils Lake Sioux Indian Reservation) was established on the south shore of Devils Lake in the summer of 1867 as a result of a treaty between the United States Government and the Sisseton, Wahpeton, and Cut Head Sioux Indians. No Indians, however, lived in the area. In the winter of 1868, two traders with an interpreter traveled to the Mouse River, inviting the Sioux, who were in a state of semi-starvation, to go into Fort Totten. A small force of warriors returned with the traders to determine whether the invitation had been made in good faith. Returning to their people, the warriors indicated the invitation had been in good faith, and the Indians began to move onto the reservation (Athearn, 1967).

By 1870, the U.S. Agent on the Sisseton Indian Agency recommended that Fort Totten have its own Indian Agent. In 1871, Major William Forbes, the first U.S. Indian Agent for Fort Totten, arrived. In 1874, at the request of Major Forbes, the Catholic Mission established a school on the Fort Totten Reservation (Athearn, 1967). When the soldiers left Fort Totten in 1890, the entire fort was turned over to the Department of Interior.

In its earlier years, the fort was used principally as winter quarters for as many as five companies. It was one of a series of forts established to protect an overland travel route, from southern Minnesota into Montana and the main channel of communication from the Missouri River northeast. Troops from Fort Totten escorted surveyors of the Northern Pacific Railroad and of the International Boundary Commission and they participated in various campaigns in Dakota and Montana. The original log structures were supplanted in 1886 by buildings erected half a mile north, from bricks made on the reservation (Athearn, 1967).

St. Michael's, the mission school conducted by the Grey Nuns of Montreal since 1874, was consolidated with the Indian Industrial School and housed with the agency offices in the fort buildings until 1959, when the fort was abandoned for educational use (McHarness, 1974). The present St. Michael's School, located at the town of St. Michael, North Dakota, was purchased by the tribal council in 1972. The old wooden buildings of the fort gradually are being restored to their original appearance through the efforts of service clubs in Devils Lake, and will be restored more completely when the current program for Fort Totten land use and recreational planning has been completed. The reservation today covers about 410 square miles and includes parts of Benson, Eddy, and Nelson Counties (U.S. Dept. of Commerce, 1974).

The Fort Laramie Treaty of 1868, made with the Indians by the U.S. Government, agreed to keep non-Indians from hunting or settling on Indian territory and to pay annuities for appropriate Indian lands. It also established a great Sioux Indian Reservation, which was to include all of what is now South Dakota west of the Missouri River, except for the Crow Creek, Yankton, and Lake Traverse (Sisseton) Reservations. By the end of 1868, nearly half the Sioux were gathered onto reservations (Hassrick, 1967).

In 1868, an Agency for the Standing Rock Sioux was established at Ashley Island above the mouth of the Grand River on the Missouri River. The Agency was moved to Fort Yates, N. D., in 1873, causing the Indians to abandon 650 acres under cultivation at the Grand River Agency. The Standing Rock Indian Agency was established by an executive order on January 11, 1875, for the Teton Sioux and for a number of years beginning June 6, 1875, the War Department stationed a small garrison at the site of the present Fort Yates (Washburn, 1973).

Standing Rock's agent, Burke, said in his yearly report of 1876 (the year in which Custer was defeated) that the defiance of the hostiles had little effect on the Indians of Standing Rock. One hundred of the younger men went to join Sitting Bull against the advice of their chiefs (Washburn, 1973). Burke's report, like the writings and official reports sent to Washington, or the non-Indian portion of North America, was similar to those that appear repeatedly in the archives. They reflect little knowledge of Indian culture and no sympathy for any Indians who rejected acculturation and gauged their own success by the docility (or apparent acculturation) of the Indians in the areas they commanded (McLaughlin, 1936).

By act of Congress on March 2, 1889, a military post was established on the reservation at the present town of Fort Yates and named after Capt. George W. Yates of the Seventh Cavalry, who was killed at the Battle of the Little Big Horn. A garrison was maintained at the fort until 1895 when the War Department decided to construct a new post at Bismarck because Fort Yates had no railroad. Fort Yates was abandoned in September, 1903, and the Standing Rock Indian Reservation was opened for settlement by white settlers on February 4, 1913 (Washburn, 1973). The reservation today covers a total of 1,667 square miles (U.S. Dept. of Commerce, 1974).

In 1863 the Red Lake and Pembina bands of Chippewa turned over all lands they held in North Dakota. The treaty, signed by the Red Lake and Pembina bands, provided for the cession of a strip of land in the northeastern part of the state. This strip was occupied by the Turtle Mountain band, who claimed they had held it before 1863. They refused to recognize the treaty, and their claim was recognized by the Federal Government (Washburn, 1973).

In 1882, the government, in response to pressure from white settlers, restored nine million acres to the public domain. This was done without the consent of, or payments of any kind to the Turtle Mountain band of Chippewa Indians. The Indians immediately sent a group to Washington to present their claims. This delegation succeeded in having a tract of land withdrawn from sale and settlement. In December, 1882, the land, 32 miles by 24 miles, was set apart as a reservation for the Turtle Mountain Chippewa Indians. In 1884, twenty townships, designated as the reservation, were returned to public domain. By 1892, an agreement had been reached, whereby the Turtle Mountain Chippewas were divested of their rights for the sum of $1,000,000 for 10,000,000 acres, 10 cents an acre (Brochin, 1969).

The two townships of the Turtle Mountain Indian Reservation have little industry and an unemployment rate of 42 percent (U.S. Dept. of Commerce, 1974).

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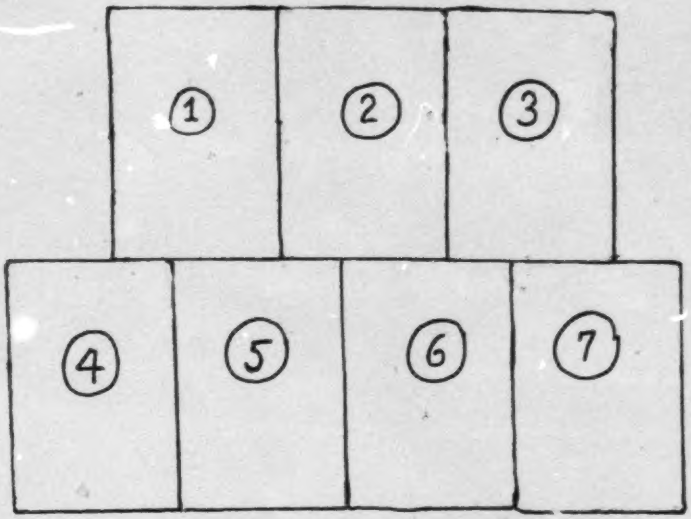
GEOLOGIC MAP OF THE FORT BERTHOLD INDIAN RESERVATION

In the next 7 pages the map of Fort Berthold will be divided into 7 sections corresponding to the diagram below:



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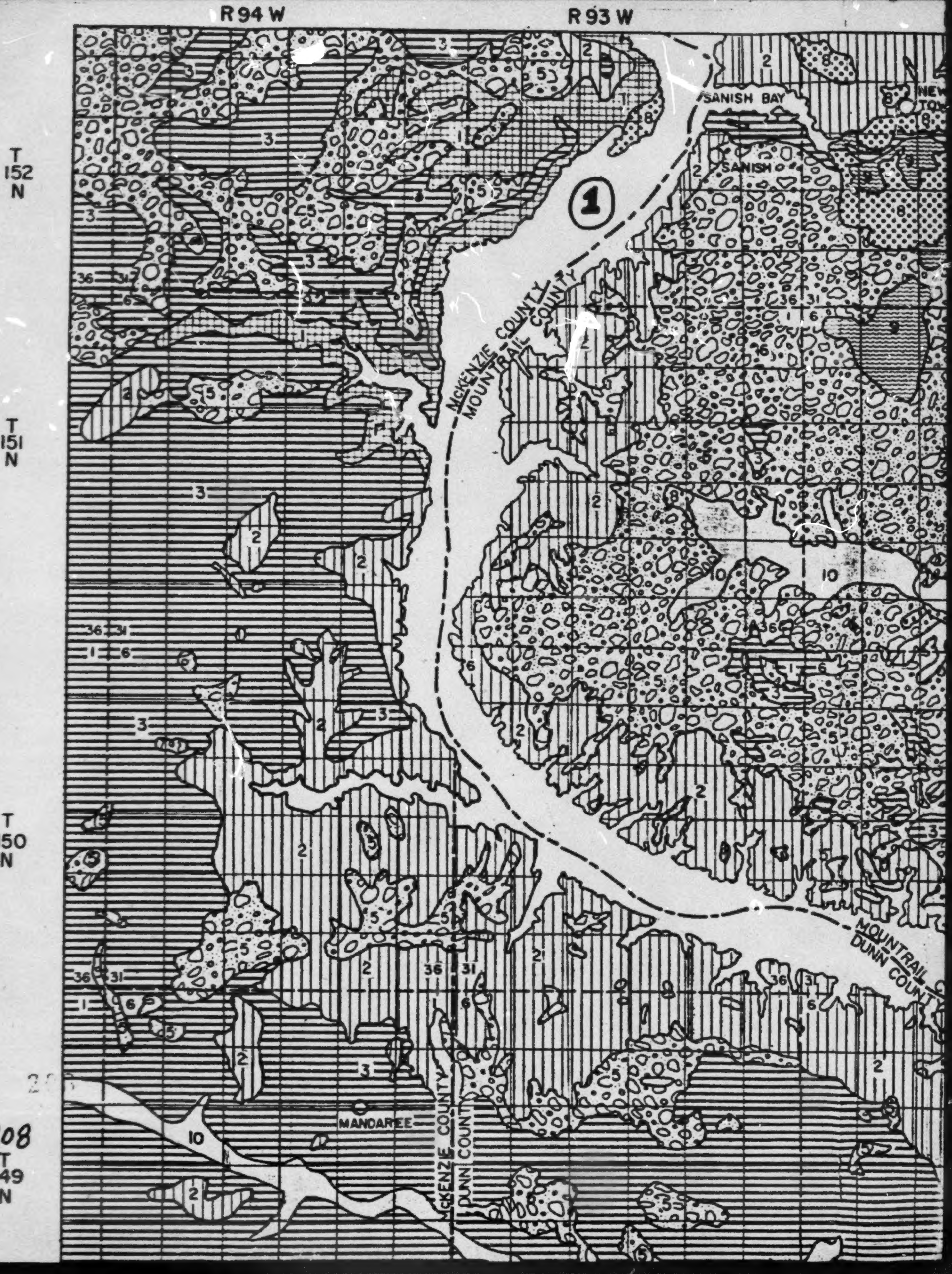
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R93W
T 152 N
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SANISH BAY
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①
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DUNN COUNTY
MANDAREE
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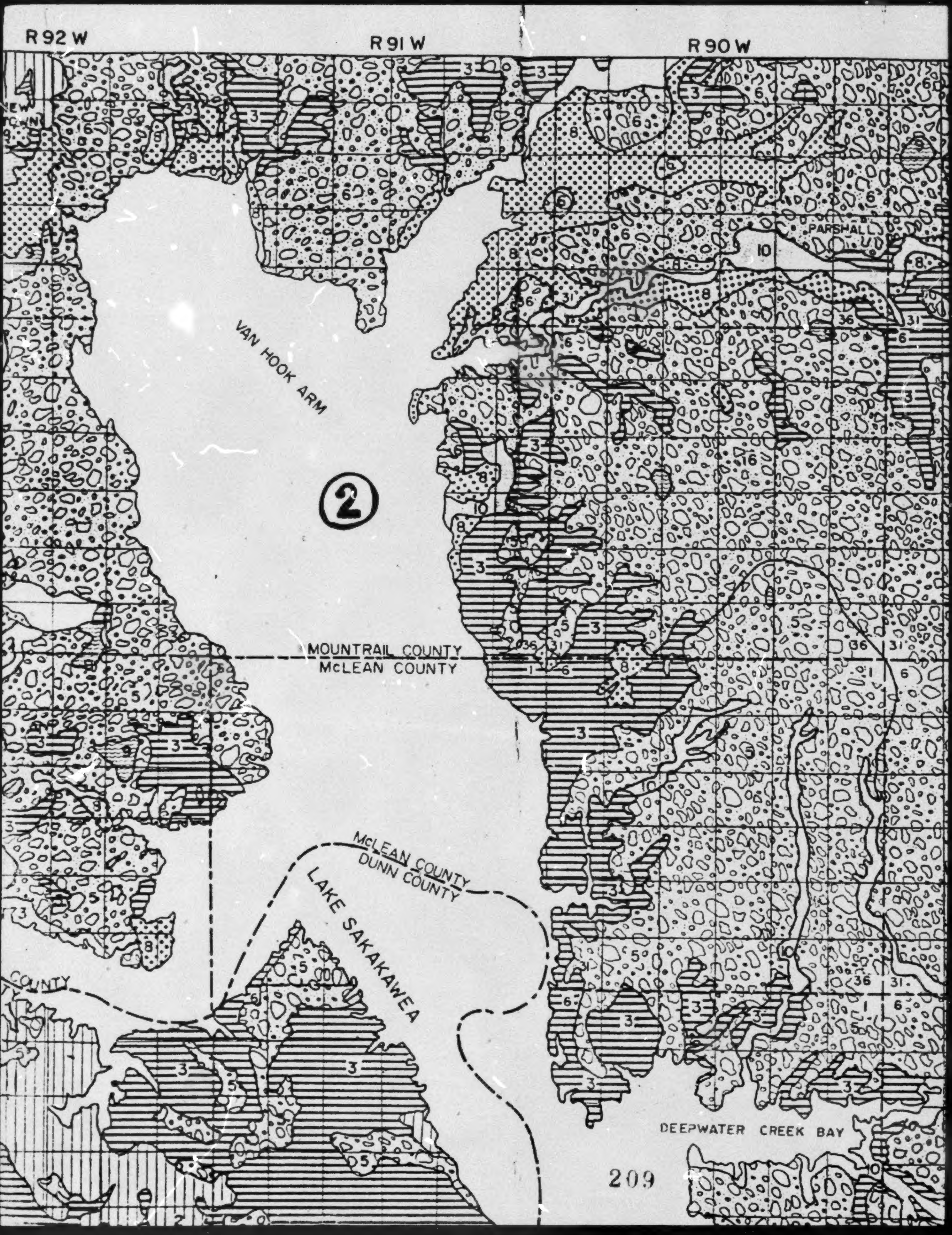
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R91 W
R90 W
NEW TOWN
PARSHALL
VAN HOOK ARM
②
MOUNTRAIL COUNTY
McLEAN COUNTY
McLEAN COUNTY
DUNN COUNTY
LAKE SAKAKAWEA
COUNTY
DEEPWATER CREEK BAY
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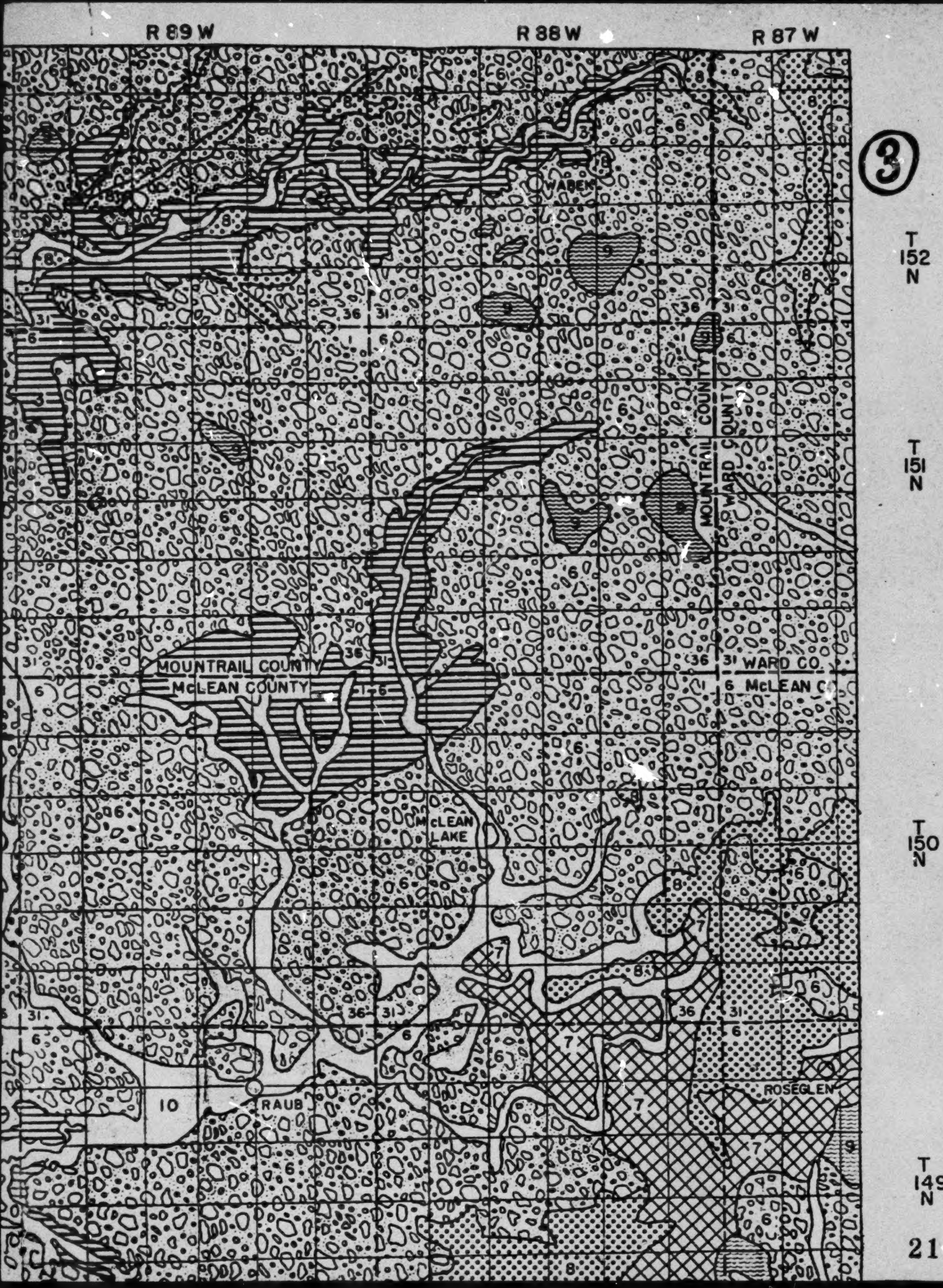
16

③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WARD COUNTY
WARD CO.
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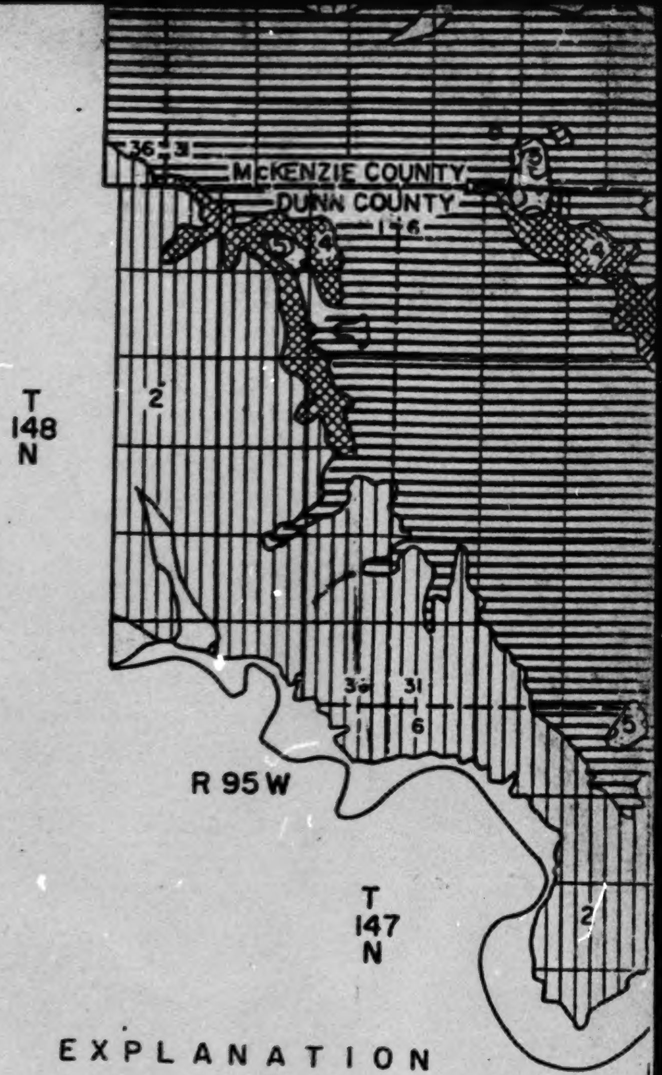
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147
N
2

EXPLANATION

Holocene

Walsh Formation

10 Silt, clay, and sand; alluvial deposits
Stream floodplains; flat topography

Pleistocene

Coleharbor Group

9 Silt and clay; lake sediment
Lake plains; flat topography

8 Gravel and sand; alluvial deposits
Glacial outwash and terraces; flat topography

7 Clay, silt, sand, and boulders (till); glacial deposits
End moraines; hilly topography

6 Clay, silt, sand, and boulders (till); glacial deposits
Ground moraine; rolling topography

5 Clay, silt, sand, and boulders (till); glacial deposits
Thin, discontinuous till cover, rolling topography

Eocene

Paleocene

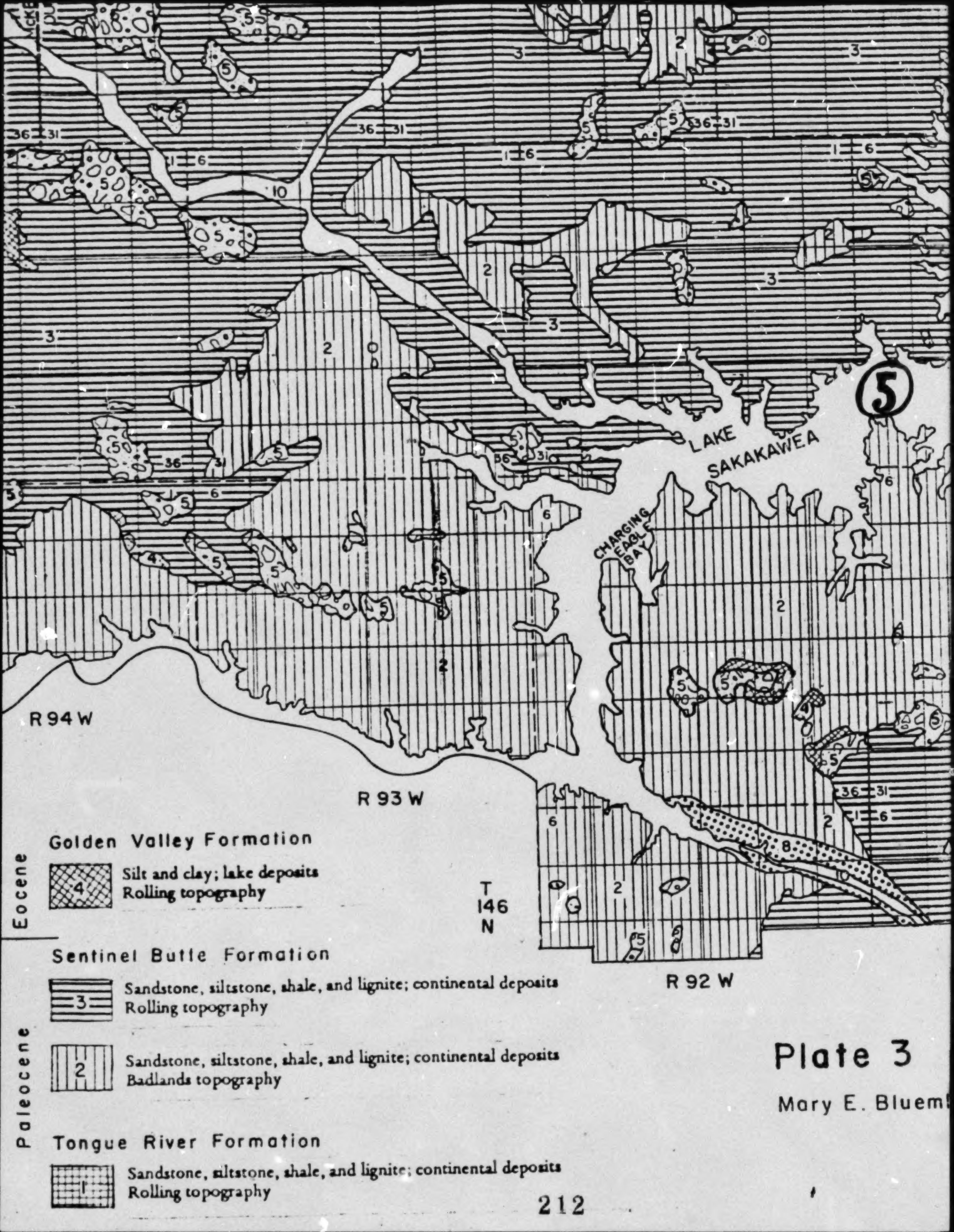
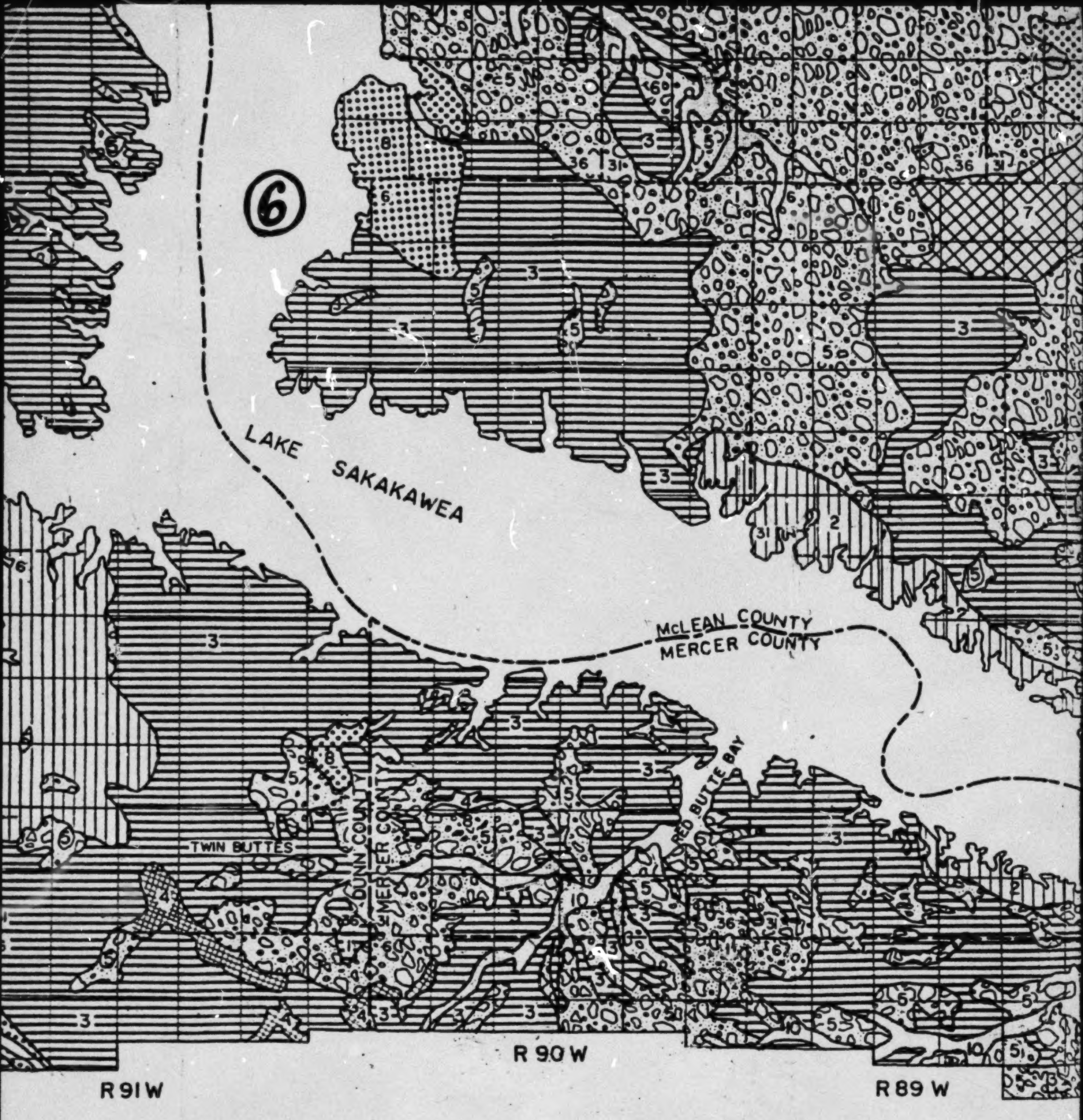

LAKE SAKAKAWEA
CHARGING EAGLE BAY
R 94 W
R 93 W
R 92 W
T 146 N
36 31
1 6
Eocene
Paleocene
Golden Valley Formation
4 Silt and clay; lake deposits
Rolling topography
Sentinel Butte Formation
3 Sandstone, siltstone, shale, and lignite; continental deposits
Rolling topography
2 Sandstone, siltstone, shale, and lignite; continental deposits
Badlands topography
Tongue River Formation
1 Sandstone, siltstone, shale, and lignite; continental deposits
Rolling topography

Plate 3

Mary E. Bluem


⑥
LAKE SAKAKAWEA
McLEAN COUNTY
MERCER COUNTY
DUNN COUNTY
MERCER COUNTY
TWIN BUTTES
RED BUTTE BAY
R 91 W
R 90 W
R 89 W
0 1 2 3 4 MILES
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5
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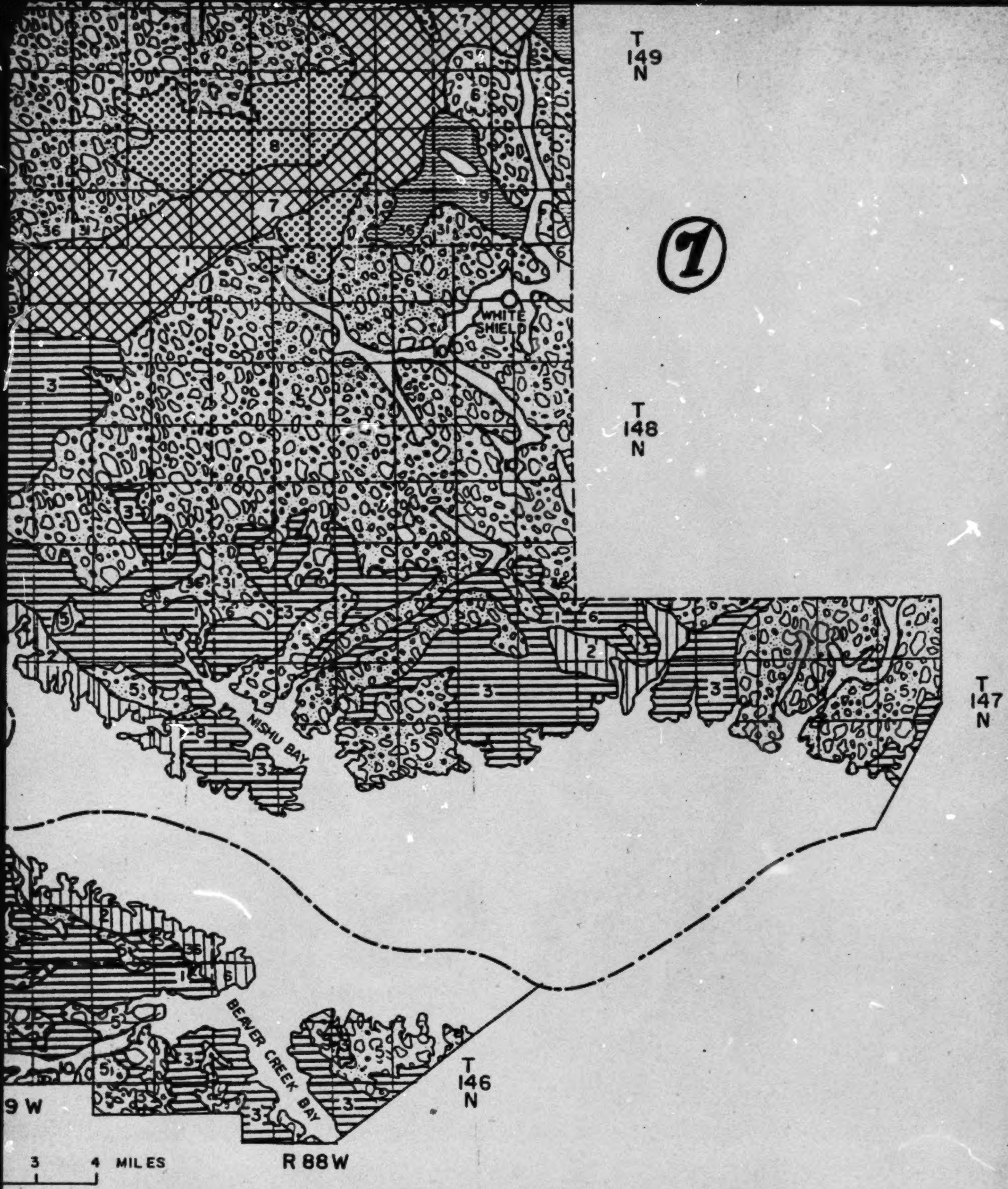
31
36

3 GEOLOGIC MAP OF THE FORT BERTHOLD I

luemle

This map is modified from Bluemle (1971), Carlson (1973), Clayton (1970), and from an unpublished map by Lee Clayton.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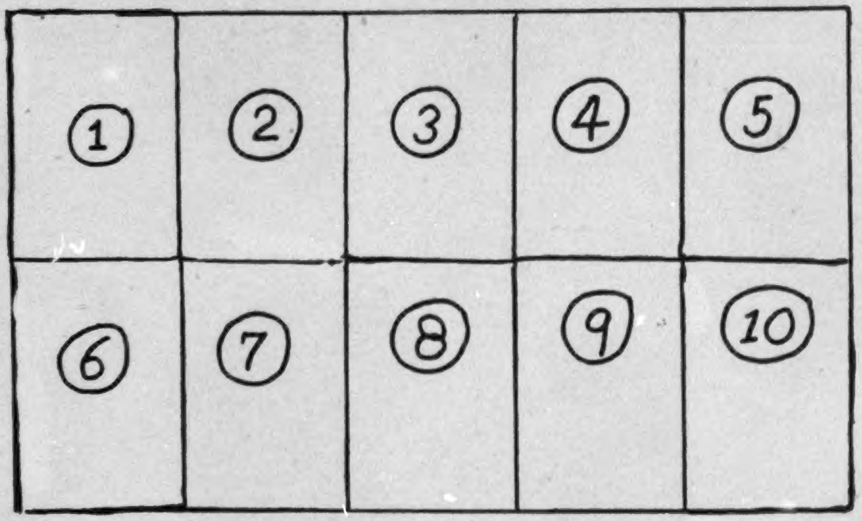
⑦
WHITE SHIELD
T 148 N
T 147 N
NISHU BAY
BEAVER CREEK BAY
T 146 N
9 W
R 88 W
3 4 MILES

THOLD INDIAN RESERVATION

GEOLOGIC MAP OF THE STANDING ROCK SIOUX INDIAN RESERVATION

In the next 10 pages the map of the Standing Rock Sioux Indian Reservation will be divided into 10 sections corresponding to the diagram below:



The numbers refer to the order the map pages are presented.

①

Plate I GEOLOGIC MAP OF THE S

Mary E. Bluemle

EXPLANATION

QUATERNARY	Holocene	11	**Walsh Formation** Fine sand; windblown deposits Dunes; hilly topography
		10	Silt, clay, and sand; alluvial deposits Stream floodplains; flat topography
	Pleistocene	9	**Coleharbor Group** Silt and clay; lake sediment Lake plains; flat topography
		8	Clay, silt, sand, and boulders; glacial deposits Thin, discontinuous till cover; rolling topography
TERTIARY	Paleocene	7	**Tongue River Formation** Sandstone, siltstone, shale, and lignite; continental deposits Rolling topography
		6	**Cannonball Formation** Sandstone, and shale; marine deposits Undulating topography
		5	**Ludlow Formation** Sandstone and shale; continental deposits Undulating and rolling topography

CRETACEOUS

②

THE STANDING ROCK SIOUX INDIAN RES

This map
unpublis
Carlson

CRETACEOUS

Hell Creek Formation

4	Sandstone, siltstone, shale: continental deposits Badlands topography
3	Sandstone, siltstone, shale: continental deposits Rolling to hilly topography

Fox Hills Formation

2	Mainly sandstone: marine deposits Rolling to hilly topography

Pierre Formation

1	Shale: marine deposits Deeply eroded topography

SYMBOLS

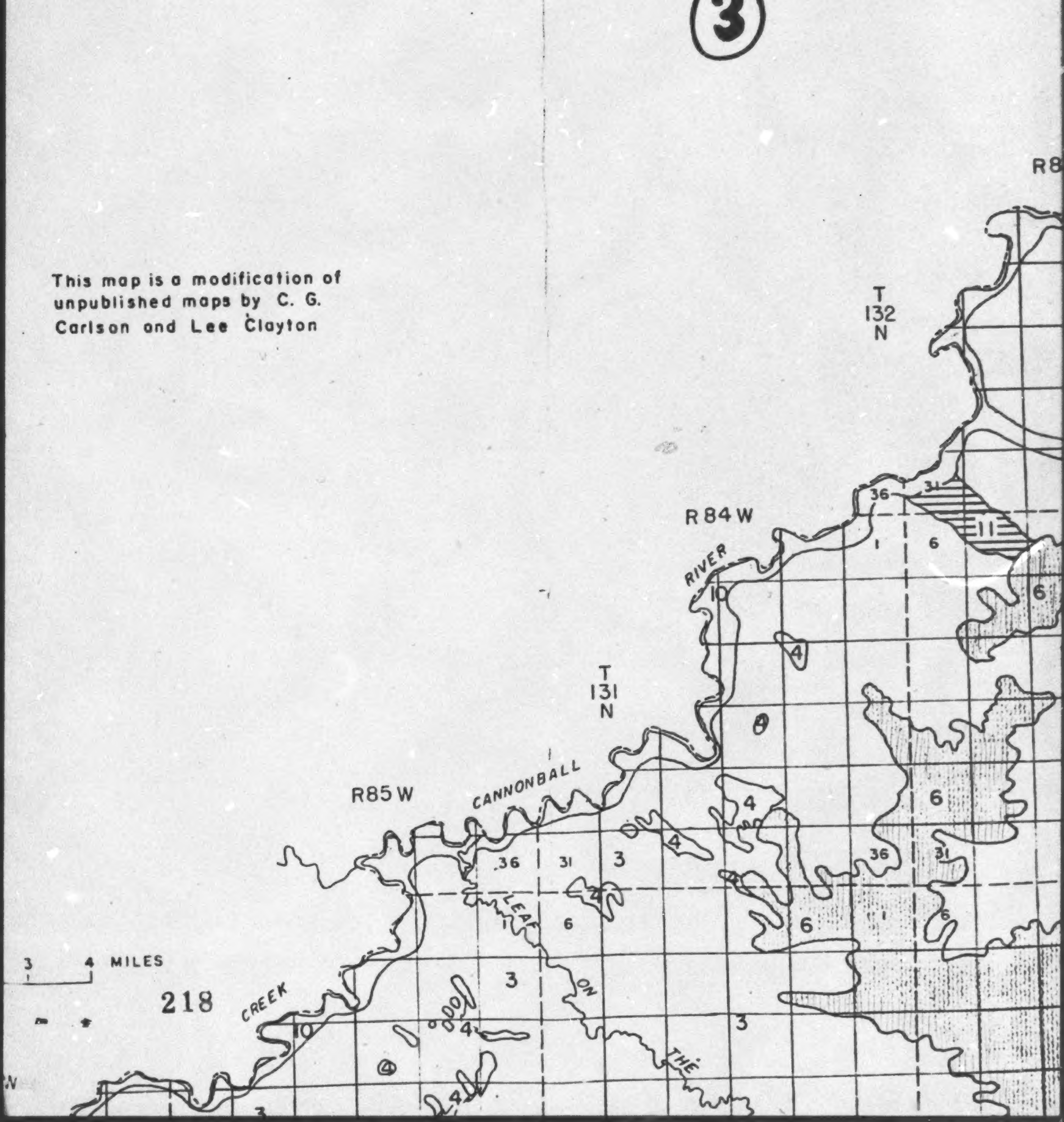
⬭	Permafrost Polygon Areas
↘	Wind Lineations
B	Blowouts

0 1 2 3 4 MILE

R86W

RESERVATION

③



This map is a modification of unpublished maps by C. G. Carlson and Lee Clayton

T 132 N
T 131 N
R84W
R85W
R8
RIVER
CANNONBALL
CREEK
LEAF ON THE
36
31
1
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11
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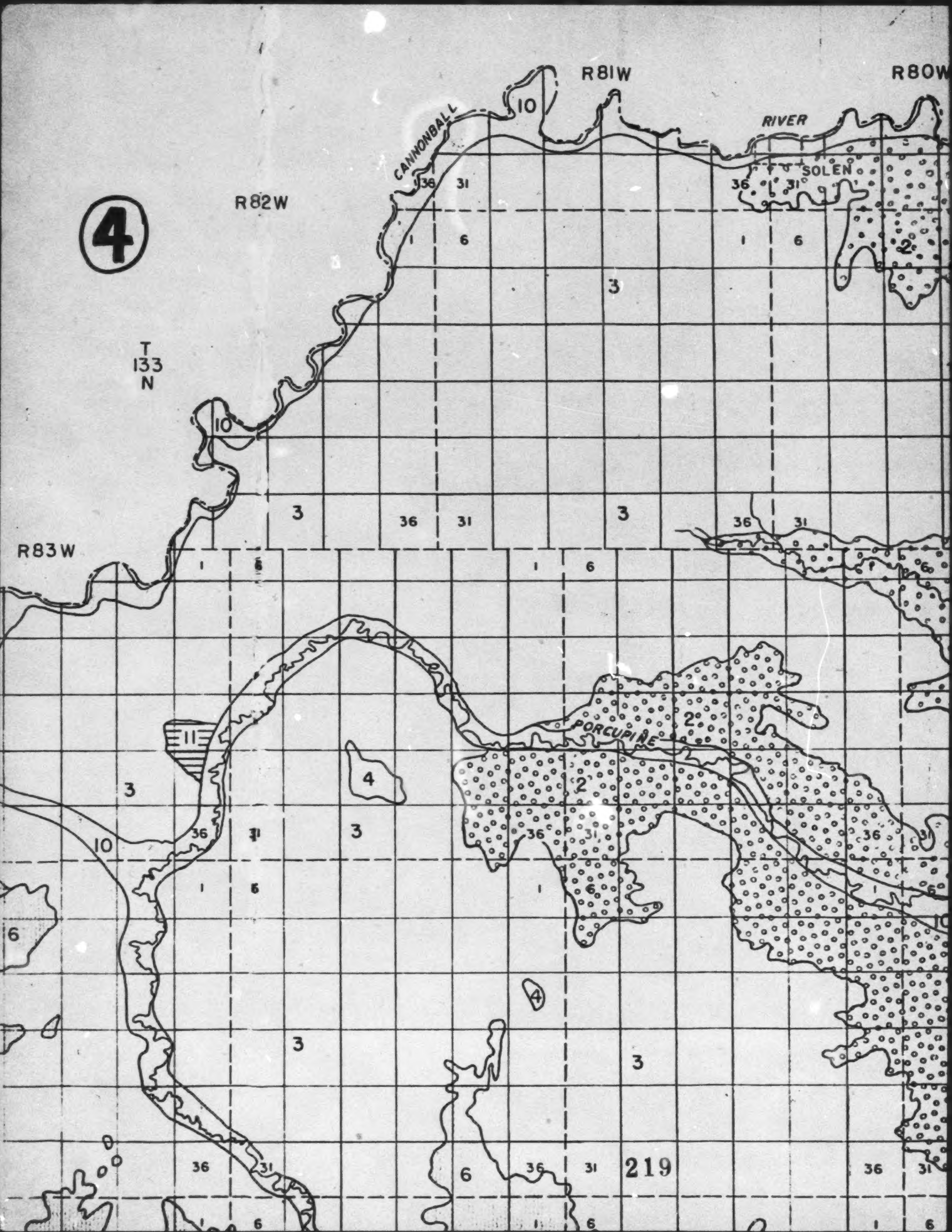
3 4 MILES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R81W
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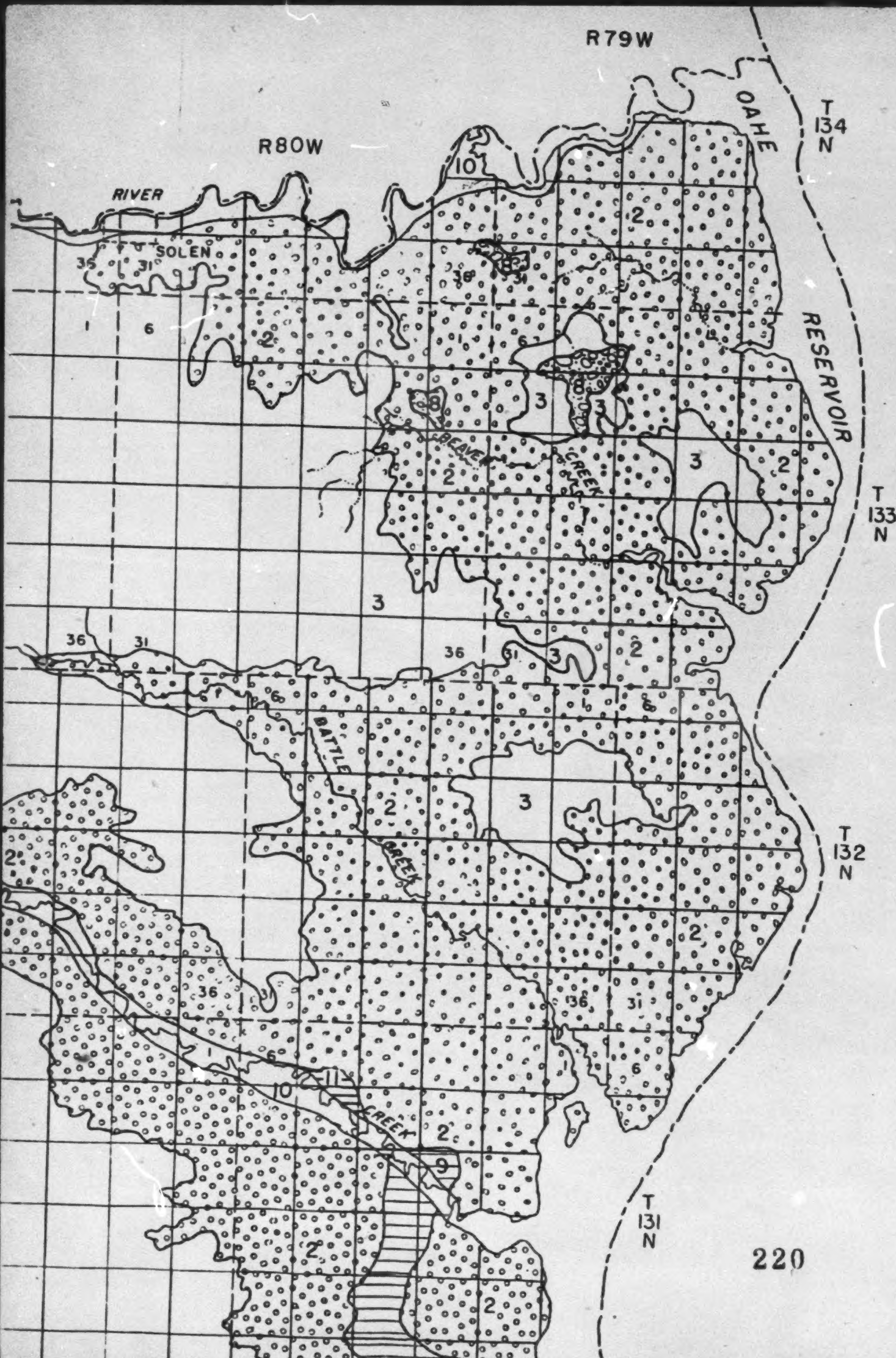
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⑤

QUATERN

Pleistocene

Coleharbor Group

9 Silt and clay; lake sediment
Lake plains; flat topography

8 Clay, silt, sand, and boulders; glacial deposits
Thin, discontinuous till cover; rolling topography

TERTIARY

Paleocene

Tongue River Formation

7 Sandstone, siltstone, shale, and lignite; continental deposits
Rolling topography

Cannonball Formation

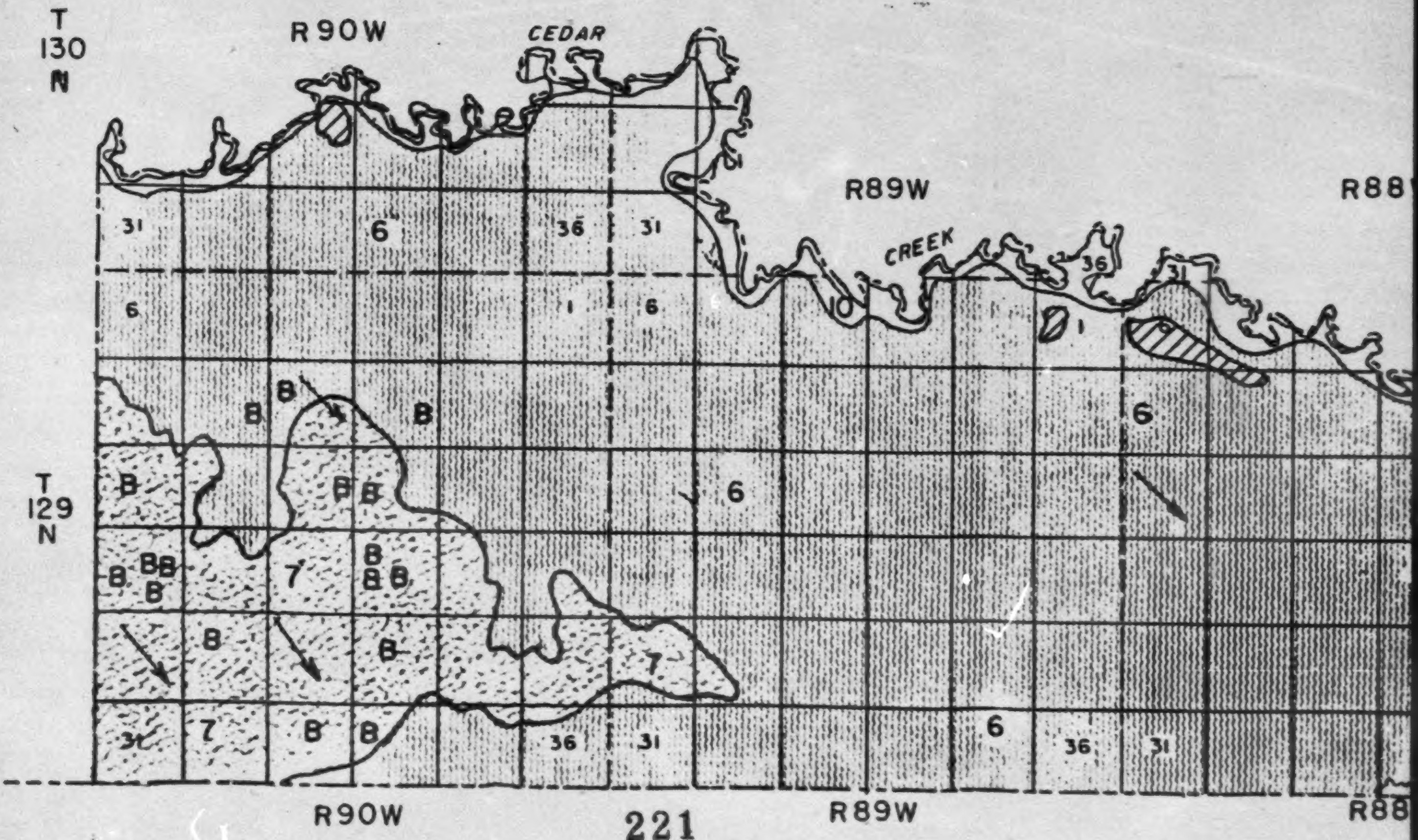
6 Sandstone, and shale; marine deposits
Undulating topography

Ludlow Formation

5 Sandstone and shale; continental deposits
Undulating and rolling topography

CRETACE

⑥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R90W
R89W
R88

CRETACE

Fox Hills Formation

▨ 2	Mainly sandstone; marine deposits Rolling to hilly topography

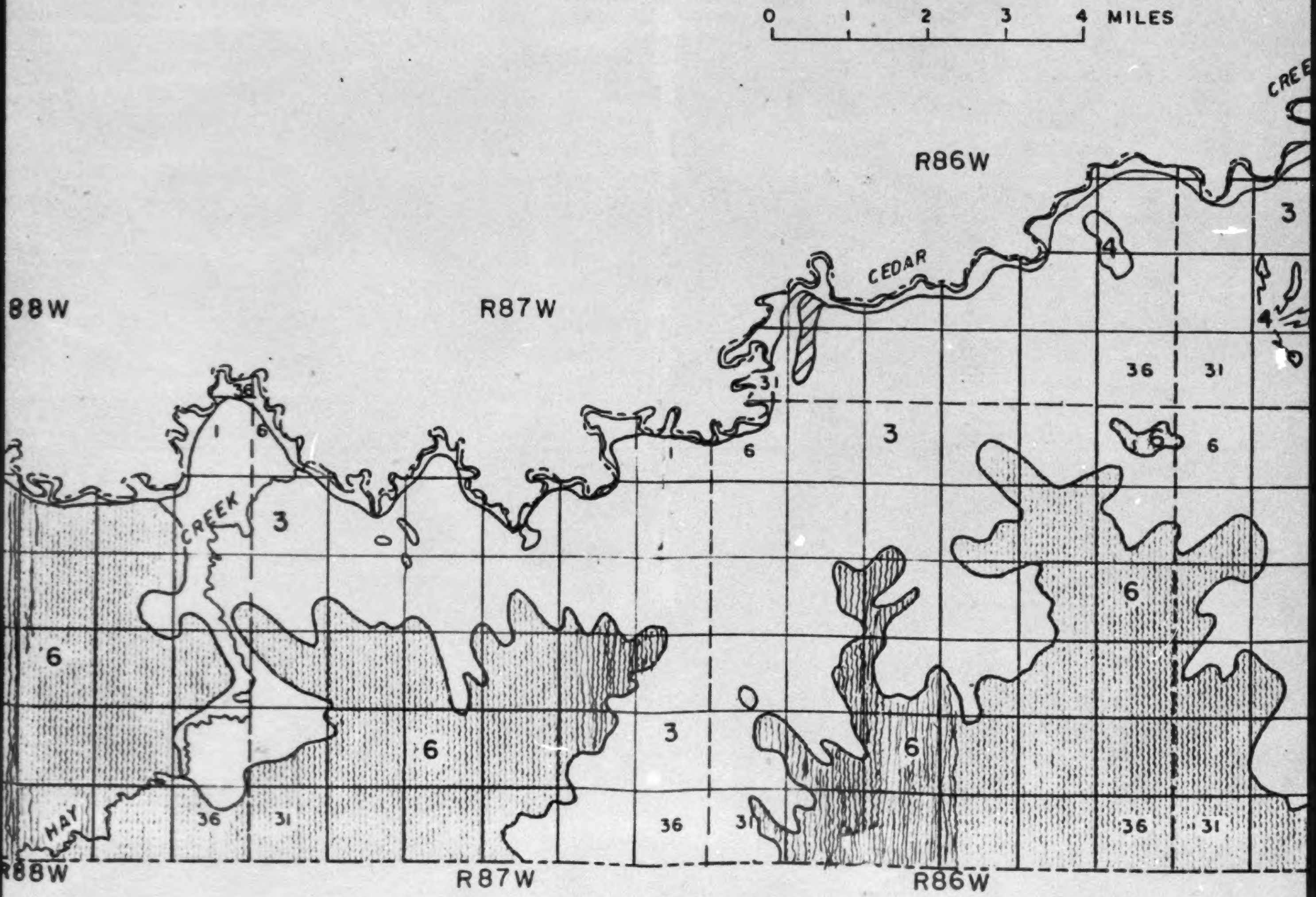
Pierre Formation

▨ 1	Shale: marine deposits Deeply eroded topography

SYMBOLS

⬭	Permafrost Polygon Areas
↘	Wind Lineations
B	Blowouts

⑦



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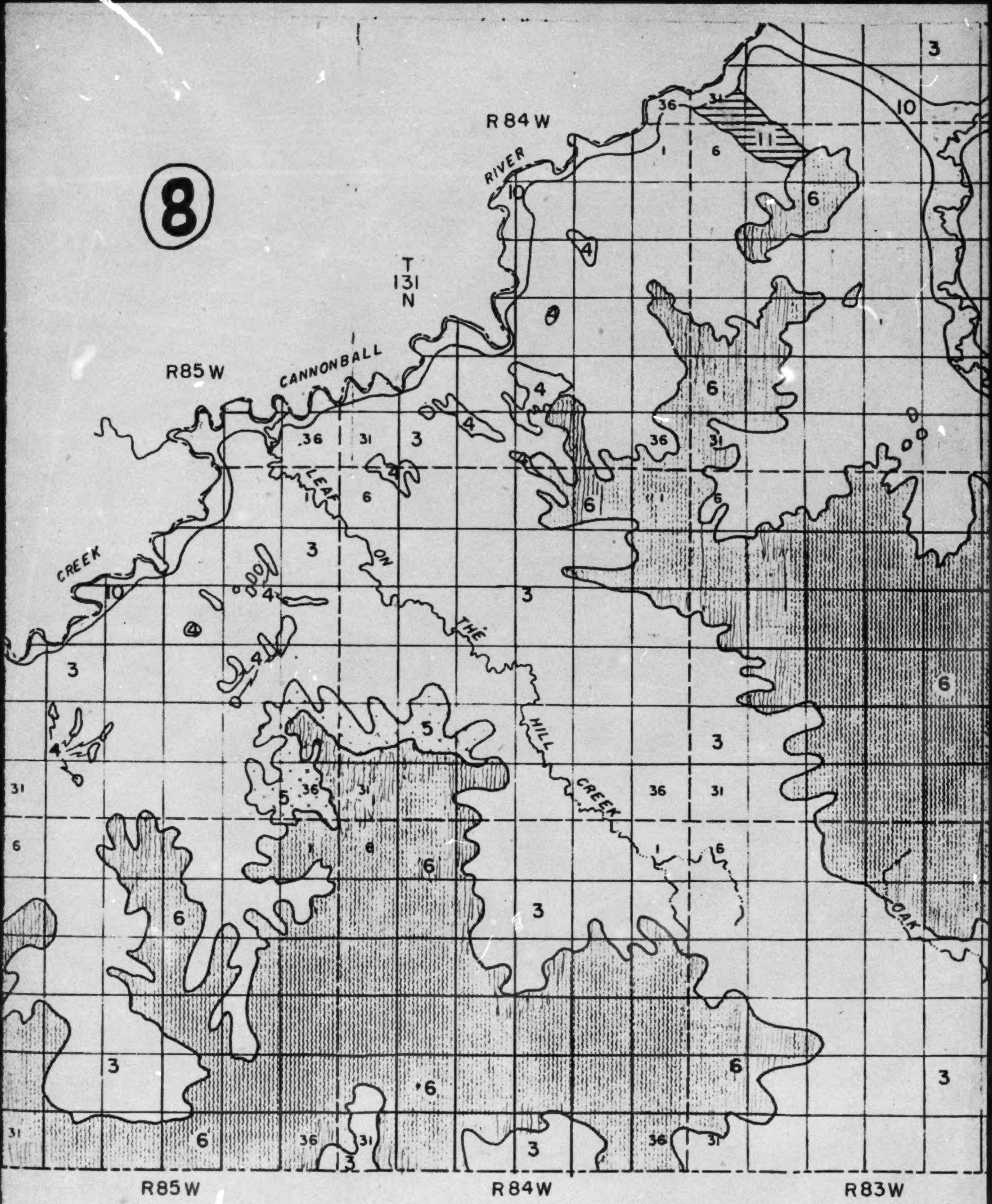
R88W
R87W
R86W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CANNONBALL
RIVER
CREEK
LEAF
ON
THE
HILL
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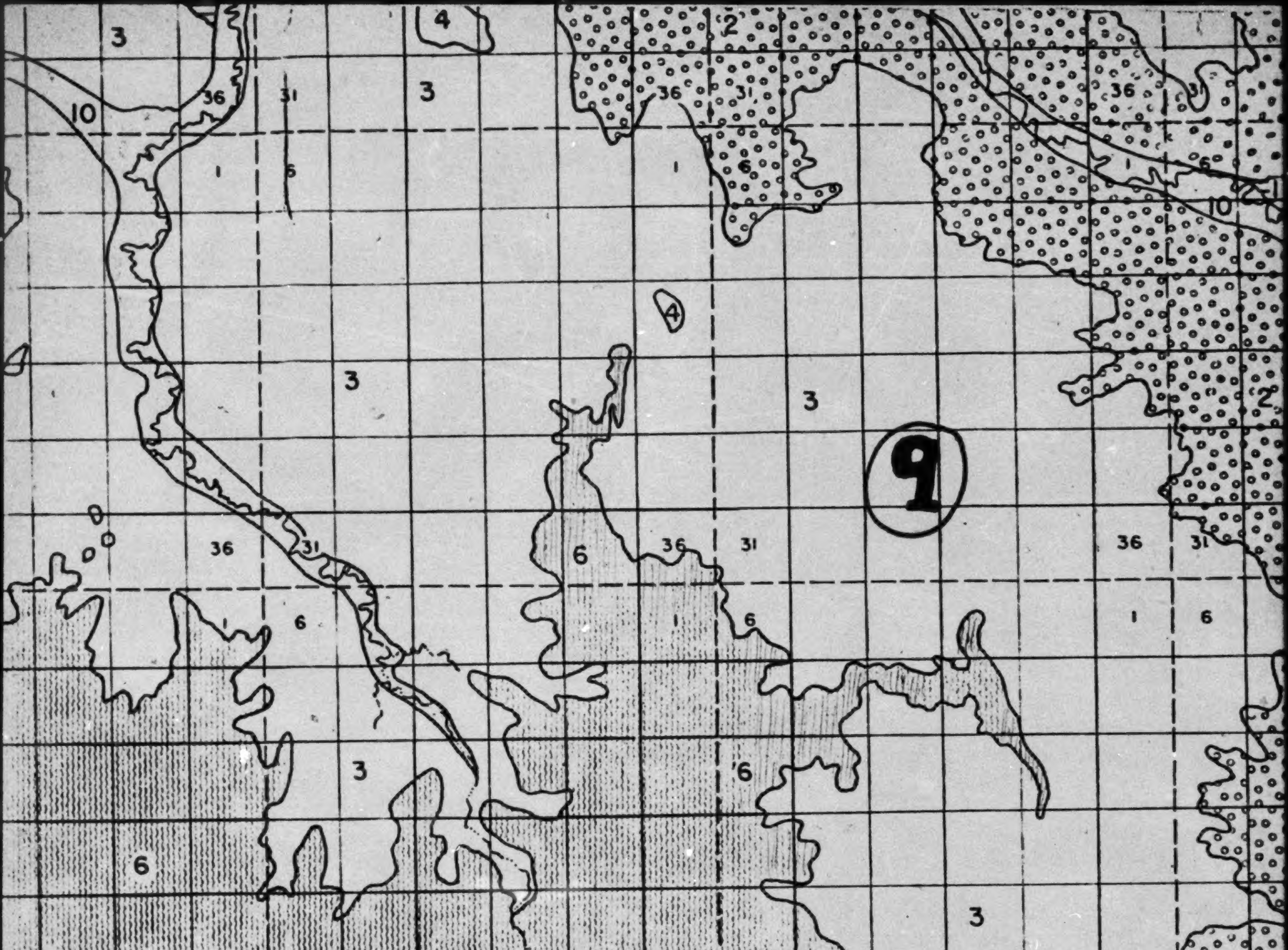
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3
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SELFRIDGE
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R83W
R82W
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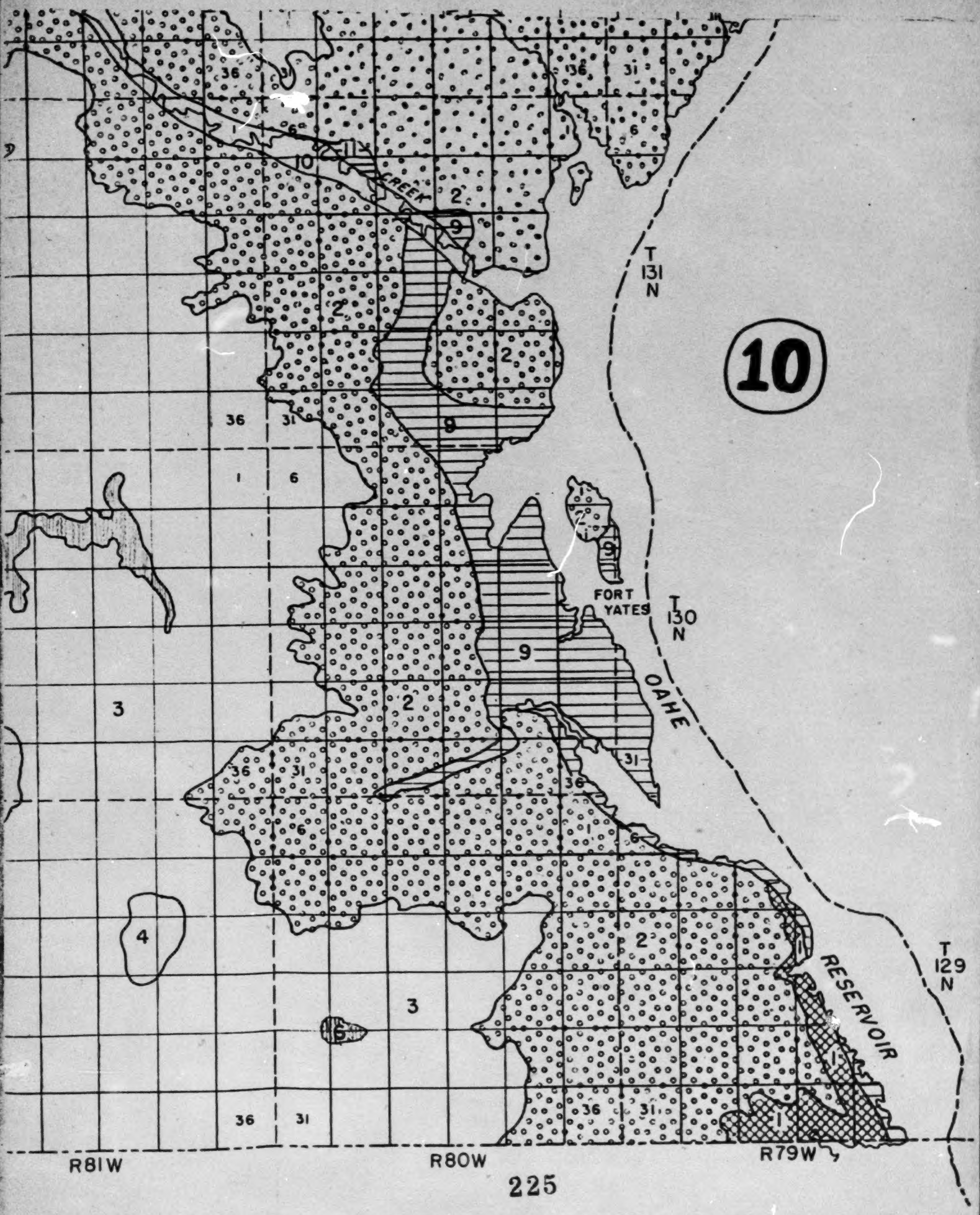

⑩
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T 130 N
T 129 N
FORT YATES
OAHE
RESERVOIR
R81W
R80W
R79W
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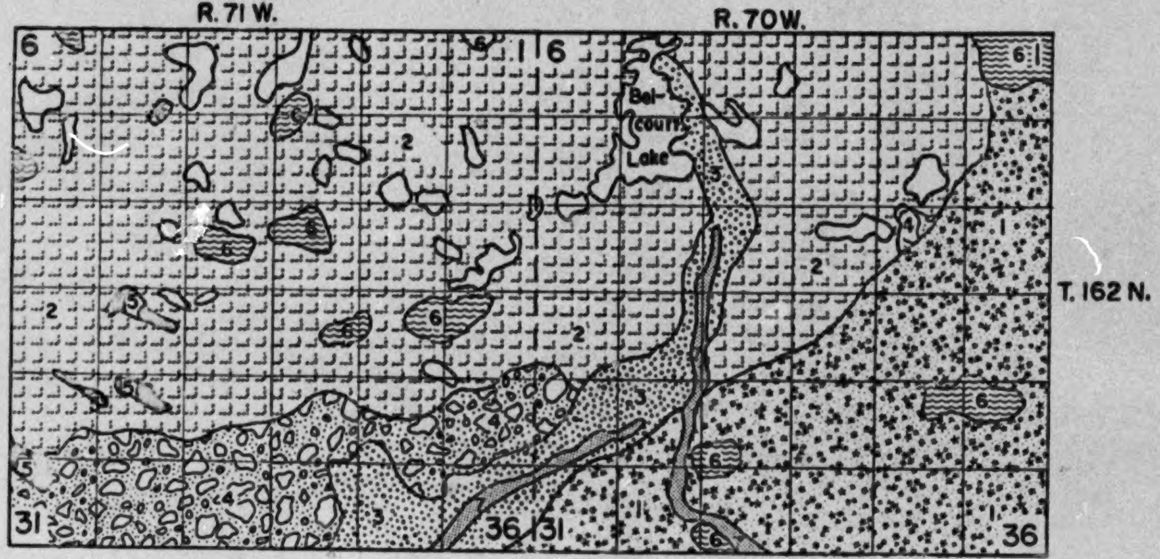
Plate 2 GEOLOGIC MAP OF THE TURTLE MOUNTAIN INDIAN RESERVATION

Mary E. Bluemle



EXPLANATION

This map is modified from Deal (1971)

QUATERNARY

Holocene

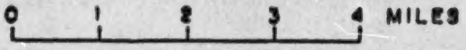
Walsh Formation

7	Silt, clay, and sand; alluvial deposits Stream Floodplains

Pleistocene

Coleharbor Group

6	Silt and clay; lake sediment Lake Plains
5	Shaly gravel and sand; ice-contact alluvial deposits Eskers
4	Sand, gravel, some boulders and till; Fluvial and colluvial deposits
3	Gravel and sand; alluvial deposits Glacial Outwash
2	Clay, silt, sand, gravel, and boulders (till); Glacial deposits Dead-ice Moraine
1	Clay, silt, sand, gravel, and boulders (till); Glacial deposits Ground Moraine



GEOLOGIC MAP OF THE DEVILS LAKE SIOUX INDIAN RESERVATION

In the next 6 pages the map of the Devils Lake Sioux Indian Reservation will be divided into 6 sections corresponding to the diagram below:

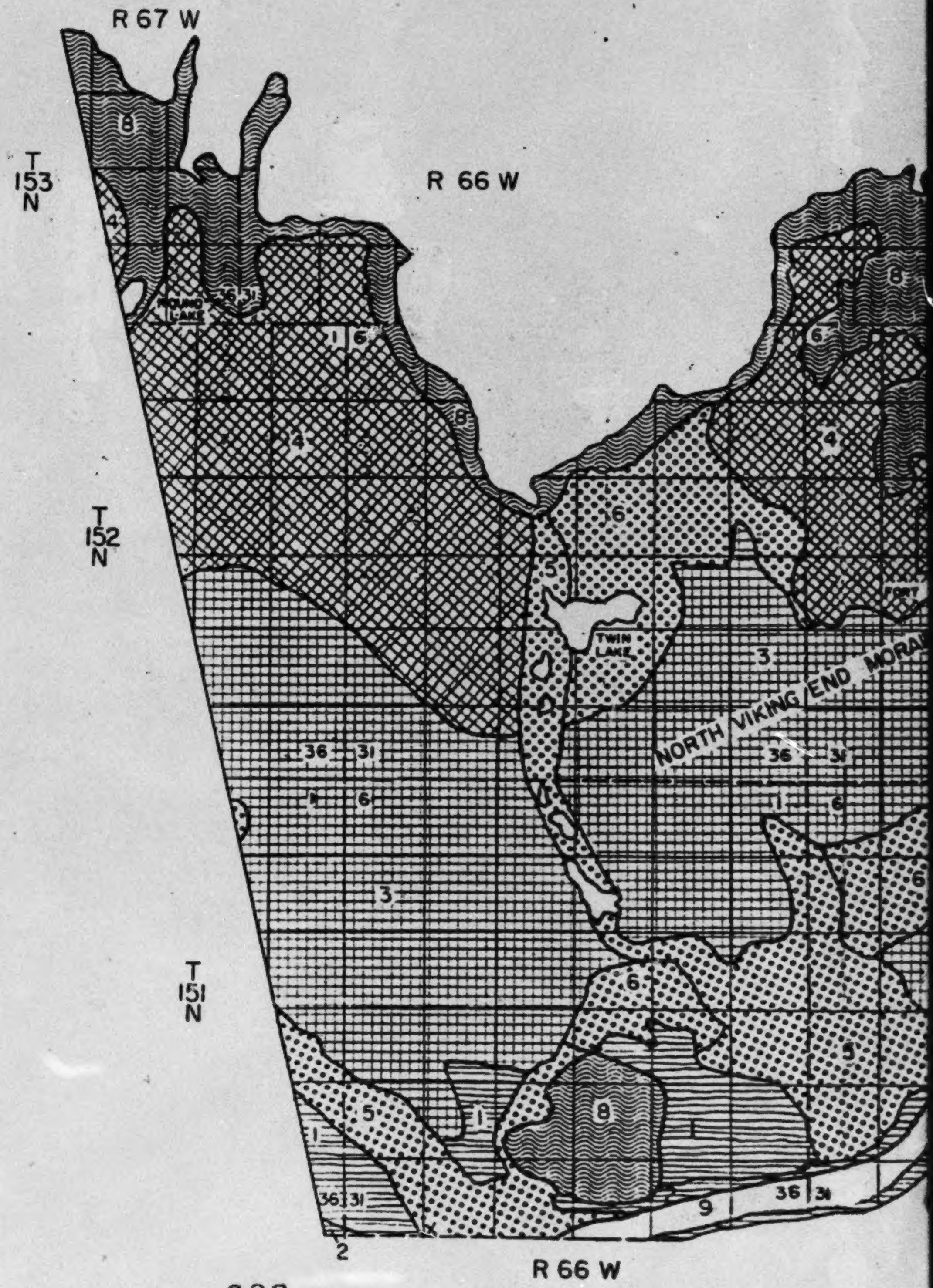
①	②	③
④	⑤	⑥

The numbers refer to the order the map pages are presented.

①

Plate 4 GEOLOGIC MAP

Mary E. Bluemle


R 67 W
R 66 W
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ROUND LAKE
TWIN LAKE
NORTH VIKING END MORA
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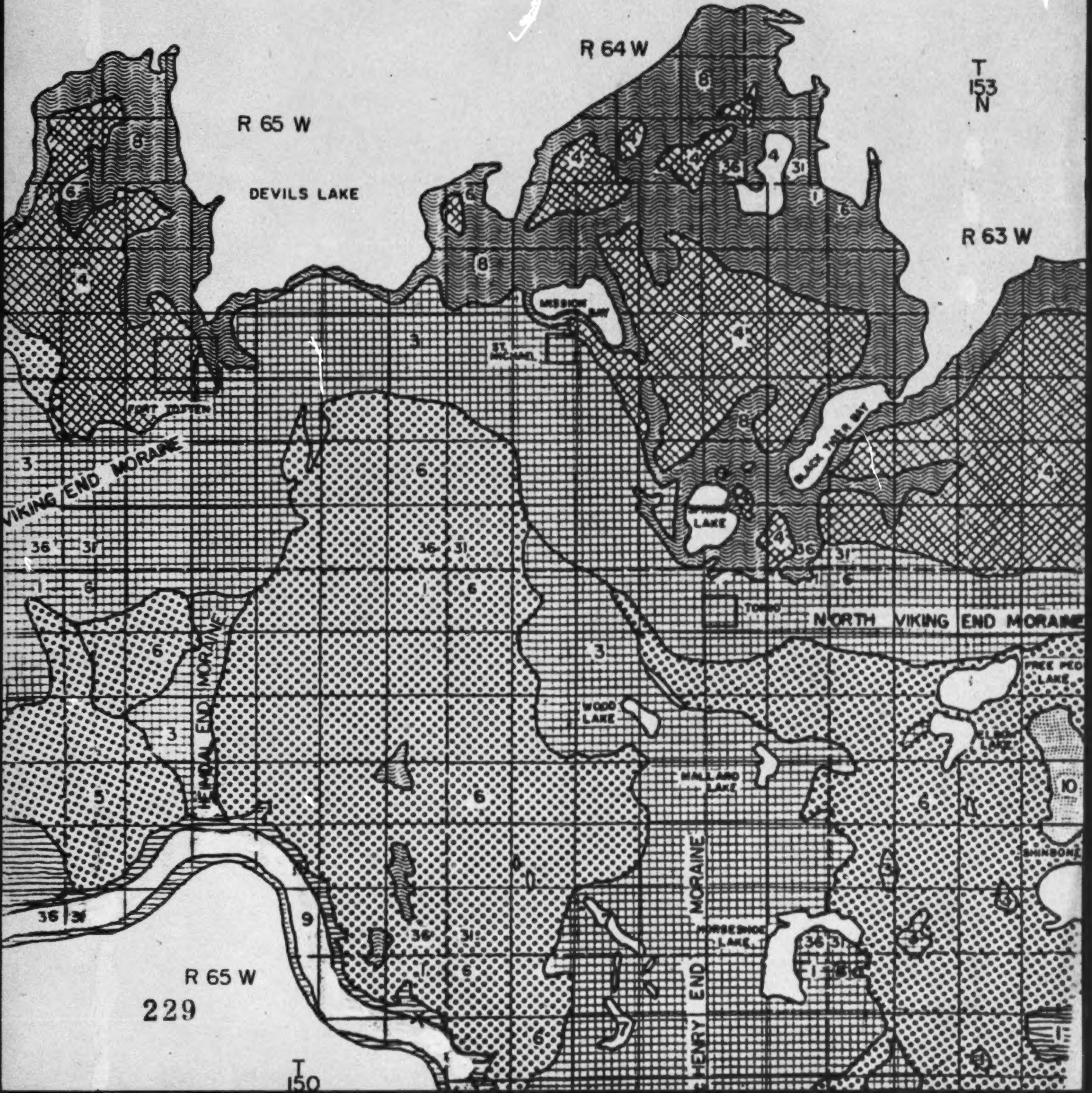
MAP OF THE DEVILS LAKE SIOUX IND

②



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DEVILS LAKE
R 64 W
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MISSION BAY
ST. MICHAEL
FORT TOTTEN
VIKING END MORAINE
LAKE
BLACK TIGER BAY
TOKIO
NORTH VIKING END MORAINE
FREE PEO
LAKE
WOOD LAKE
MALLARD LAKE
END MORAINE
HENRY END MORAINE
HORSESHOE LAKE
SHINBONE
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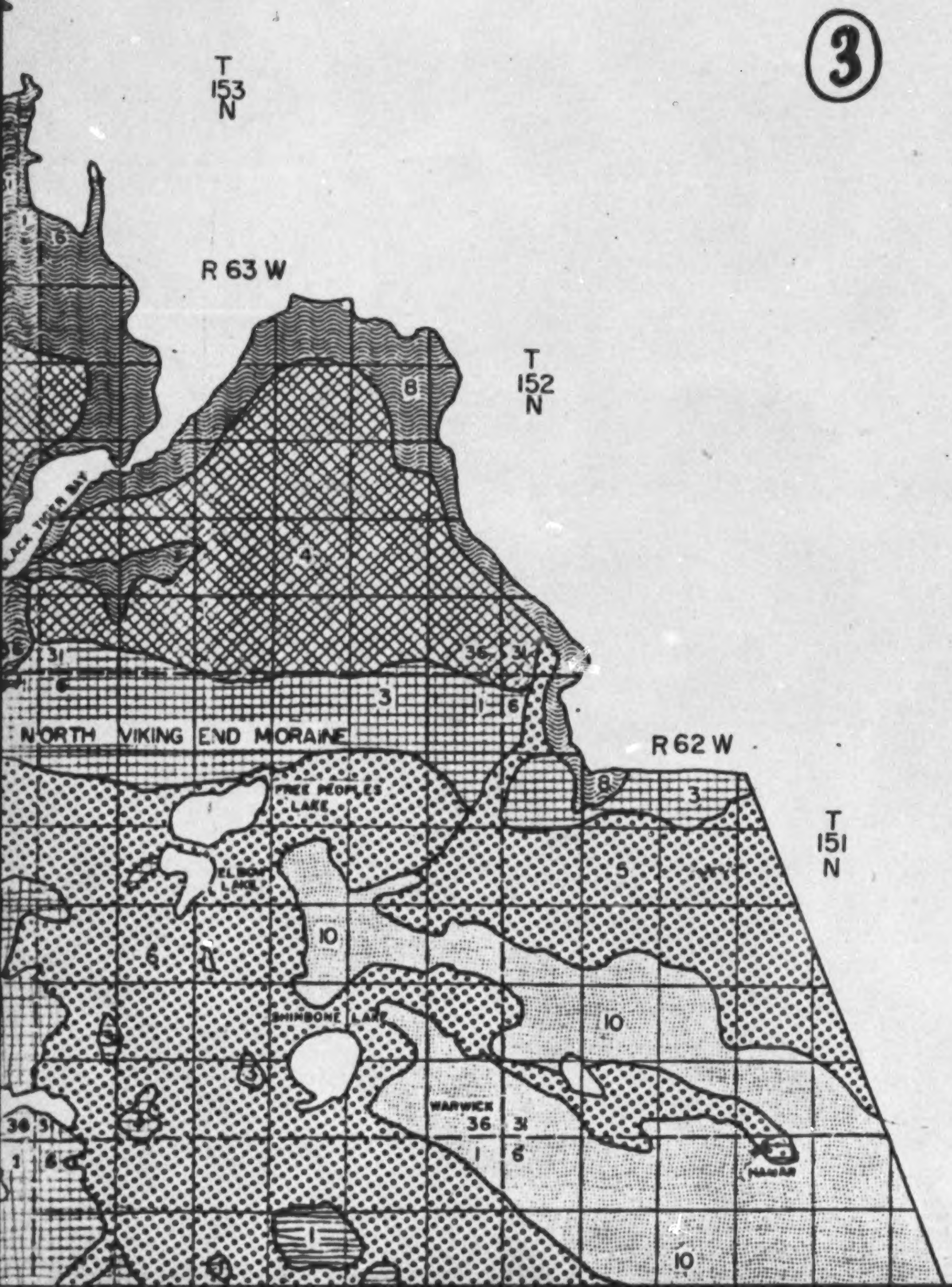
SIOUX INDIAN RESERVATION

③



T 153 N
R 63 W
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BLACK TIGER BAY
NORTH VIKING END MORAINE
FREE PEOPLES LAKE
ELBOW LAKE
SHINBONE LAKE
WARWICK
HAMAR
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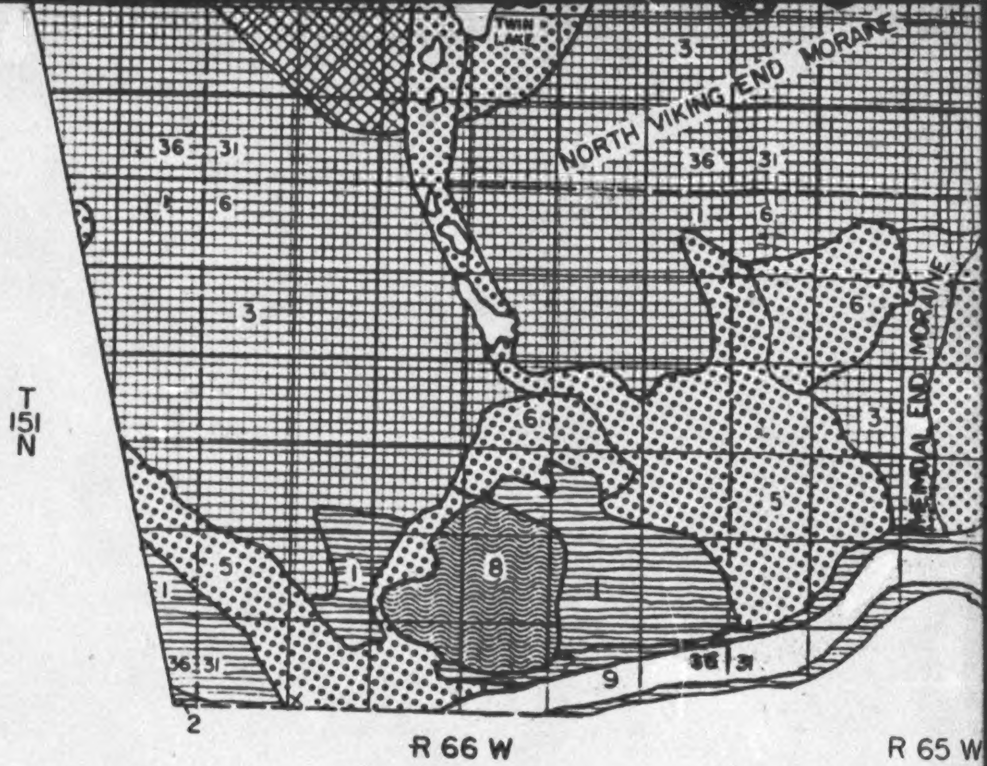
TWIN LAKE
NORTH VIKING END MORAINE
END MORAINE
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T 151 N
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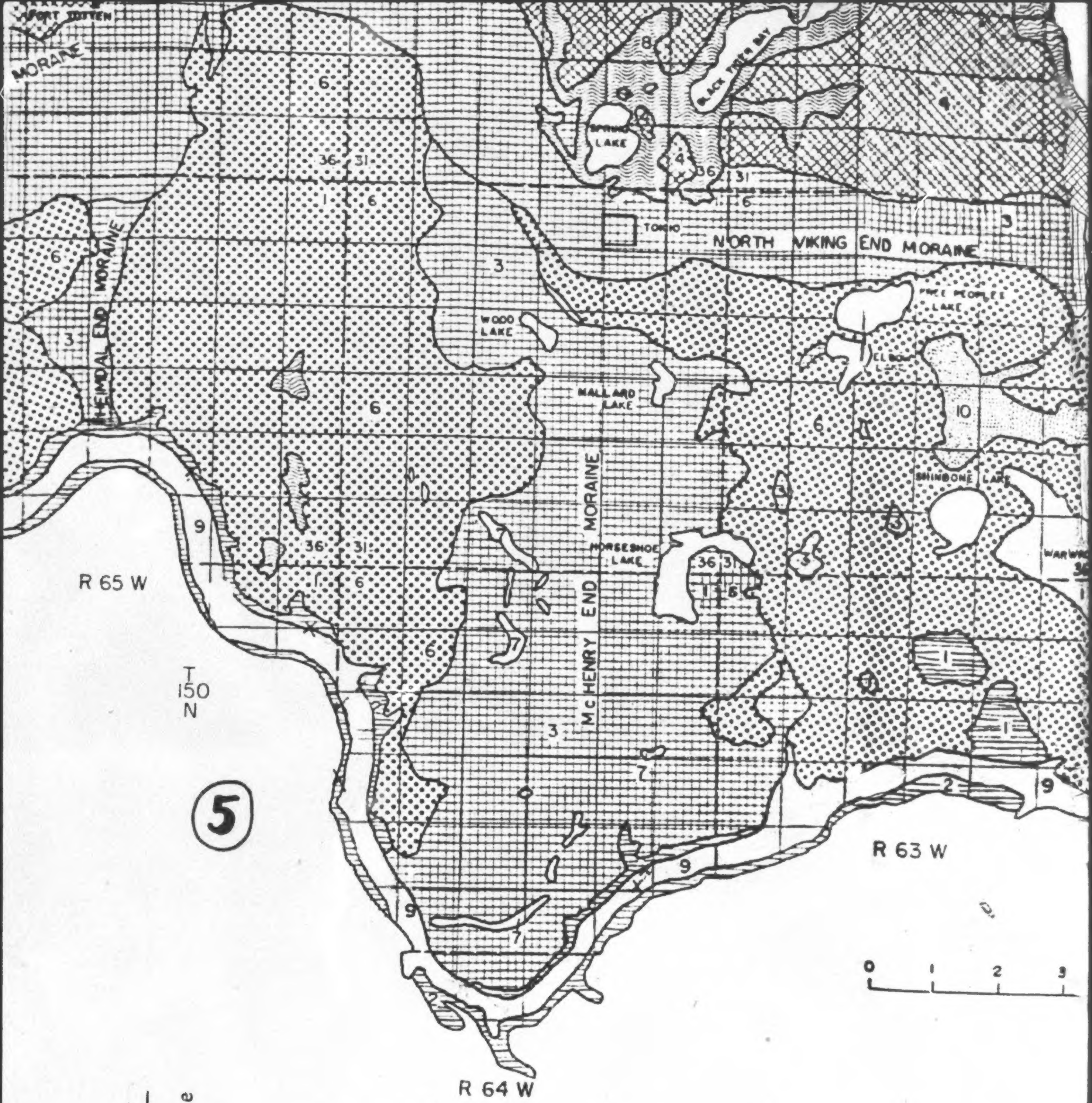
EXPLANATION

Walsh Formation

Holocene	10	Fine sand; windblown deposits Dunes; hilly topography
	9	Silt, clay, and sand; alluvial deposits Stream floodplains; flat topography

Coleharbor Group

Pleistocene	8	Silt and clay; lake sediment Lake plains; flat topography
	7	Gravel and sand; ice-contact alluvial deposits Eskers; ridges
	6	Gravel and sand; alluvial deposits Collapsed glacial outwash; rolling topography
	5	Gravel and sand; alluvial deposits Glacial outwash; flat topography
	4	Clay, silt, sand, and boulders (till); glacial deposits Dead-ice moraine; hummocky topography
	3	Clay, silt, sand, and boulders (till); glacial deposits End moraines; hilly topography


FORT TOTTEN
MORAINE
HEIMDAL END MORAINE
SPRING LAKE
BLACK TIGER BAY
TOKIO
NORTH VIKING END MORAINE
WOOD LAKE
MALLARD LAKE
FREE PEOPLES LAKE
ELBOW LAKE
SHINBONE LAKE
HORSESHOE LAKE
McHENRY END MORAINE
WARWICK
R 65 W
R 64 W
R 63 W
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0 1 2 3
36 31 1 6
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Pleistocene

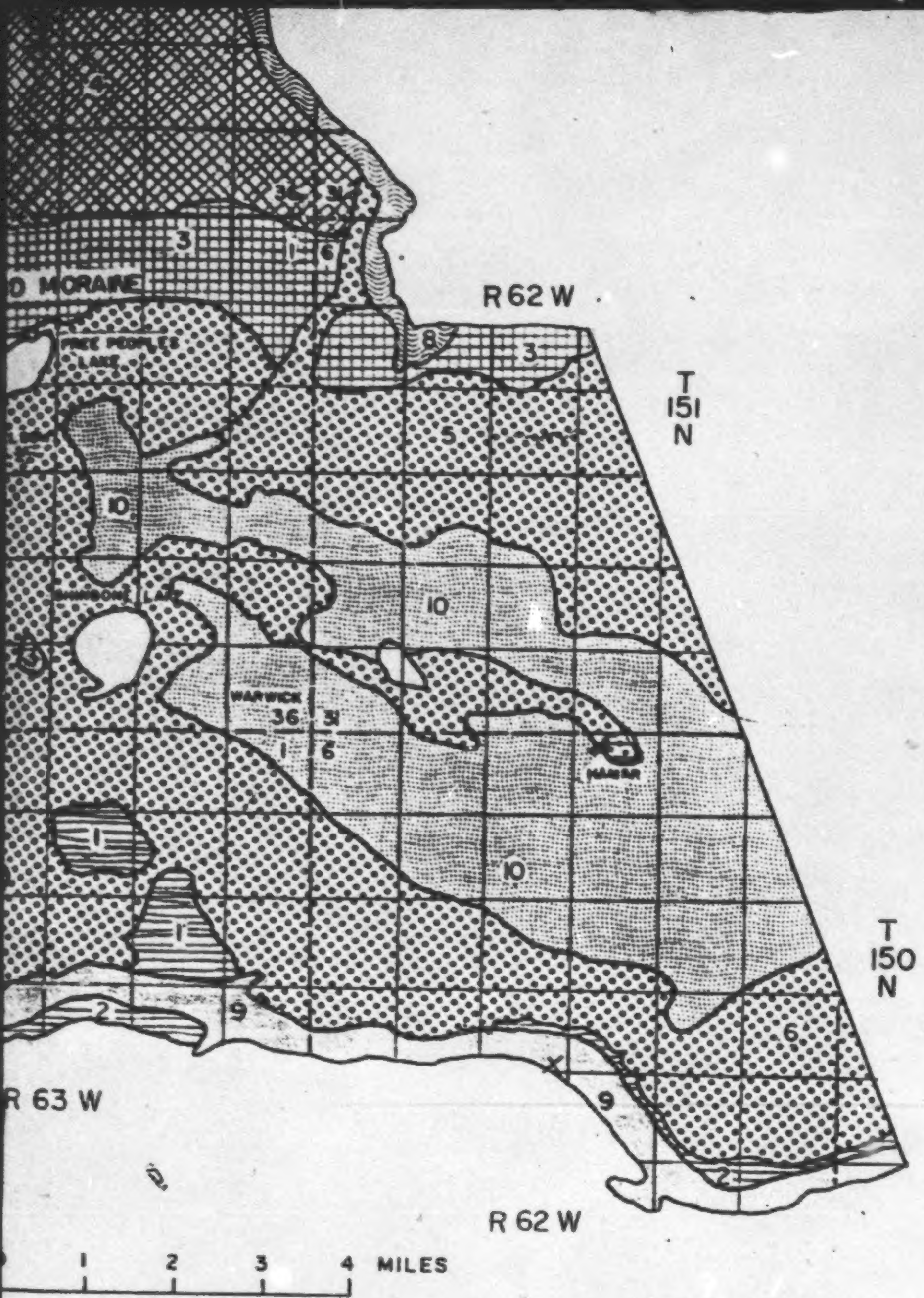
2 Clay, silt, sand, and boulders (till); glacial deposits
Steep slopes along the Sheyenne River valley

1 Clay, silt, sand, and boulders (till); glacial deposits
Ground moraine, rolling topography

retaceous

Pierre Formation

X Exposure of shale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0 1 2 3 4 MILES

⑥

This map is modified from Bluemle (1965) and Carlson and Freers (1975).